A COMPLETE SYSTEM OF GENERAL GEOGRAPHY:

EXPLAINING

The Nature and Properties of the EARTH:

VIZ.

It's Figure, Magnitude, Motions, Situation, Contents, and Division, into Land and Water, Mountains, Woods, Desarts, Lakes, Rivers, &c.

With particular Accounts of the different Appearances of the Heavens in different Countries; the Seasons of the Year over all the Globe; the Tides of the Sea; Bays, Capes, Islands, Rocks, Sand-Banks, and Shelves.

The State of the Atmosphere; the Nature of Exhalations; Storms, Tornados, &c.

The Origin of Springs, Mineral Waters, Burning Mountains, Mines, &c.

The Uses and Making of Maps, Globes, and Sea Charts.

The Foundations of *Dialling*; the Art of *Measuring Heights* and *Distances*; the Art of Ship-Building, *Navigation*, and the Ways of *Finding the* LONGITUDE at SEA.

Originally Written in LATIN

By *BERNHARD VARENIUS*, M. D.

Since Improved and Illustrated.

By Sir ISAAC NEWTON and Dr. JURIN;

And now Translated into *English*; with additional *Notes*, *Copper-Plates*, an *Alphabetical Index*, and other Improvements.

Particularly useful to Students in the *Universities*; Travellers, Sailors, and all those who desire to be acquainted with *Mixed Mathematics*, *Geography*, *Astronomy*, and *Navigation*.

By Mr. *DUGDALE*.

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I HAVE perused this SYSTEM of GENERAL GEOGRAPHY; and I do recommend it as the most Useful Book upon this Subject.

JAMES HODGSON,

Master of the Royal Mathematical School, *and* Fellow of the Royal Society.

Christ-Hospital,
Dec. 14, 1732.

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THE RELATIVE PART OF Universal Geography.

BOOK II.

Of the Properties of Places on the Earth, that arise from the apparent Motion of the Stars.

CHAP. XXII.

PRELIMINARIES.

WE have thitherto treated of *Geography, absolutely considered*; we come now to the second Part of this Doctrine, in which we shall consider the Properties of the Earth that depend on the apparent Motion of the Sun and Stars, and would not exist if that Motion did not appear: the Explication of which will more properly belong to *Geo-*

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4

graphy, if we ſuppoſe the Earth to move, as in *Chap.* vi. And for underſtanding hereof we muſt premiſe the following Definitions and Hypotheſes.

DEFINITIONS.

1. THE *Artificial Terreſtrial Globe* is a Globe made by Art, on whoſe Superficies the Parts of the Earth are repreſented, in their proper places, in the ſame proportion which the Globe's Superficies hath to that of the Earth.

A *Map*, or *Geographical Table*, is a plain Figure, in which is repreſented the Situation of the parts of the Earth's Surface; and is *univerſal* or *particular*: the one ſhows the whole Superficies of the Earth; the other a part only. Some of them are made by ſtrait, others by curve Lines; both repreſenting the Peripheries of Circles on the Earth. The Compoſition both of Globes and Maps we ſhall ſhow at the end of this Book; for it cannot be yet underſtood.

2. *THE Poles of the Earth are two fixed Points diametrically oppoſite, at the ends of the Axis, about which the Earth revolves; and are exactly under the two Points in the Heavens about which the Stars ſeem to revolve.* The Pole that is under the *Bear* is the North, or Arctic, Pole; the other the South, or Antarctic, Pole: which is better underſtood by ſeeing them on the Globe than by Words.

'3. THE *Zenith* and *Nadir* are the Poles of the
' Horizon; the former being the Point directly over
' our Heads, and the latter that directly under
' our Feet.'

4. THE Equator is the Periphery of a great Circle on the Earth, equally diſtant from the two Poles, and is called the Equinoctial Line; or the Line, by Sailors in the way of Eminence; and to it are all the Circles (deſcribed by the diurnal Mo-

tion of the Stars) parallel; and therefore the Equator is that on which their diurnal Motion is meaſured.

5. THE *Circles* called *Parallels to the Equator* are the leſſer Peripheries parallel to it. On the Artificial Globe the Equator is more conſpicuous than the Parallels or Circles of Latitude, and is divided into three hundred and ſixty Degrees.

THESE may be alſo ſhown on the *Uuiverſal Geographical Maps*, whoſe curve Lines meet in the Poles. Thoſe Maps that have only ſtrait Lines have not the Poles, but the Meridians are ſuppoſed to terminate in them. The Equator in both is a ſtrait Line cutting the Meridians at right Angles, tho' in ſome particular Maps, of *Aſia* and *Europe*, 'tis curve; and alſo the Parallels are curve in curvilineal Maps, and ſtrait Lines in others.

6. THE *Ecliptic* is alſo a great Circle in the Heavens, which the Sun deſcribes by it's annual Motion: and tho' 'tis not proper to the Earth; yet 'tis drawn on the terreſtrial Globe, and is ſeen on Maps, becauſe of it's great uſe.

7. THE *Tropics* are two Circles parallel to the Equator, as far from it as the Sun goes towards the Poles; which is twenty three Degrees twenty nine Minutes, being the Angle the Ecliptic makes with the Equator; the one is called the Tropic of *Cancer*, on the North Side of the Equator; the other of *Capricorn*, on the South Side. They are marked on the Globe and Maps by a double Line with their Names. And the polar Circles are two Parallels, as far from the Pole as the Tropics are from the Equator, called *Arctic* and *Antarctic*. The Circles hitherto explained do not depend on certain places as the following do.

8. THE Meridian of a place on the Earth is the Line that paſſes from the North, over the place to the South; above which when the Sun

comes 'tis Mid-day there, or the middle between Sun rising and setting.

THEOREM.

THE Meridian of a Place passes thro' both the Poles of the Earth.

THERE are Meridians drawn on the Globe cutting every tenth or fifteenth Degree on the Equator; and the Meridian of Brass represents them all, *i. e.* if any place is brought under it, it will be the Meridian of that place.

IN right lined Maps the Meridians are strait Lines from the Top to the Bottom; but in curve lined Maps they are curve, and meet in the Poles.

'9. THE *Azimuths* are great Circles inter-'secting each other in the *Zenith* and *Nadir*, as 'the Meridians do in the Poles of the World. 'Upon them is reckoned the Sun or Stars Altitude, 'but when the *Azimuth* of the Sun or a Star is 'spoke of, we are to understand the Angle which 'the *Azimuth* that the Sun or Star is in makes 'with the Meridian, either from the North or 'South.

'10. CIRCLES of Longitude intersect each 'other in the Poles of the Ecliptic, and conse-'quently cut it at right Angles as the Meridians 'do the Equator, because the Motion of the Sun, 'Stars, or Planets, whether according or contrary 'to the succession of the Signs *Aries*, *Taurus*, '*Gemini*, &c. is reckoned upon the Ecliptic.'

11. THE *Horizon* of a place is a great Circle in the Heavens, which divides the visible part of the Heavens from the invisible part; and is called the *rational Horizon*, to distinguish it from the *visible Horizon*, which terminates our Sight round us; which is but a small Circle, and but improperly called the Horizon. It hath no fixed place on the artificial

artificial Globe; but the wooden Circle, which sustains the Globe and brass Meridian, represents every Horizon, when the place is at the Top, as shall be shown; and 'tis called the *wooden Horizon*.

THESE Definitions are necessary to the understanding what follows. We must also know from Astronomy how the Sun and Stars move.

1. THAT is the first Motion common to them all, by which in twenty four Hours they go round the Earth when they rise, pass the Meridian, and set, and rise again; and they therein seem to describe every Day Circles parallel to the Equator; as moving all on the Axis of the Earth; and thus they move fifteen Degrees on the Equator, and every Parallel, every Hour; which is the twenty fourth Part of three hundred and sixty Degrees round, as appears by the horary Circle of Brass fixed on the Meridian, at the North Pole, whereon the Index points to the Hours, as the Globe revolves.

THE second, and proper, or annual, Motion of the Sun, is that by which the Sun (or the Earth) moves from West to East; which is against the first Motion. The Time or Number of Days in which the Sun returns to the Point from which it came, is called a Year; which is three hundred and sixty five Days, and about a quarter of a Day. The path of this second Motion is called the Ecliptic, which is divided into twelve Parts, called Signs; for Astronomers have observed those Stars or Constellations of the Heavens, thro' which the Sun passes, and from these the twelve Signs receive their Names. And because they are all Animals, therefore the Ecliptic is called by the Antients the Zodiac. But properly the Ecliptic is in the middle of a Belt, which is sixteen Degrees broad; in which all the others planets move

from West to East; some nearer, others further from the Ecliptic. The Names of the Signs are comprehended in these Verses:

♈ 10 *March* ♉ ♊ ♋ 11 *June* ♌ ♍
Sunt Aries Taurus Gemini Cancer Leo Virgo

♎ 10 *Sept.* ♏ ♐ ♑ 10 *Decem.* ♒
Libraque Scorpius Arcitenens Caper Amphora

♓
Pisces.

Arcitenens is also called *Sagittarius*, *Caper Capricornus*, and *Amphora Aquarius*. The Ecliptic cuts the Equator obliquely, and it's greatest Distance is about twenty three Degrees thirty Minutes; and where the Ecliptic cuts the Equator, which is in two points, the Ecliptic begins at one of them, and the Sun in any one of these two Points makes the Days and Nights equal in all Places; and then Spring and Autumn begins; the Spring at the first of *Aries*, and the Autumn the first of *Libra*; and tho' two thousand Years ago the Signs were where the following ones are now, that is, they are gone backward, yet they retain their Names, without regard to the Stars they left.

EACH of these twelve Signs is divided into thirty Degrees, and the Sun moves fifty nine Minutes eight Seconds each Day, by going thro' three hundered and sixty Degrees in the Ecliptic, in three hundred and sixty five Days and a quarter; or we may reckon it a Degree in a Day: nor is there need for greater exactness in a small time, especially when the Design is only to instruct others. Likewise there being twelve Signs in the Ecliptic, and twelve Months in the Year, it goes thro' a Sign in a Month; but enters not the Sign in the beginning of the Month, but about the twenty first Day,

Day, according to the *Gregorian* Calendar, or the eleventh according to the *Julian*, *viz.* into *Aries*, *March* the tenth, and the tenth of *April* into *Taurus*, *&c.* or a little before, or after, the tenth Day. But if we would have the exact Knowledge of the Sun's Place it must be calculated from Tables, or taken from an *Ephemeris*: if one have a Globe, it's Place may be nearly found on the wooden Horizon; if not, they may suppose the Sun enters each Sign on the tenth Day of the Month, and then count to the present time how much is gone since; but they must be well acquainted with the Signs, and know in what Month the Sun enters any Sign. Thus the fourteenth of *March* the Sun is in the fourth of *Aries*. Thus Students ought to know where the Sun is in the Ecliptic; for 'tis mean in a Man of Letters not to know so much, whilst the Seasons, and length of the Day and Night depends on the Sun's Place, and several others things that are useful in Life.

CHAP. XXIII.

Of the Latitude of Places, and the Elevation of the Pole.

PROPOSITION I.

The Latitude of a Place, is it's Distance from the Equator.

THIS Distance is measured by an Arch from the Place in the shortest way to the Equator, or an Arch of the Meridian of that Place, from the Place to the Equator.

BUT the Latitude of the Earth is it's Extension on the Superficies from one Pole to the other; and it's Longitude is it's Extension from the West by the East to the West again, which is the Equinoctial Line: but 'tis better not to mind these Terms in Geography.

PROPOSITION II.

The Elevation of the Pole above the Horizon of a Place is an Arch of the Meridian; between either Pole and the Horizon.

IT may be said, 'tis an Arch of the Meridian on the Earth, or in the Heavens; but 'tis better referred to the Earth, supposing the Earth to cause the first Motion; yet the Definition is referred by Astronomers

Astronomers to the Celestial Meridian; and the imaginary Pole there.

PROPOSITION III.

Having the Latitude of a Place on the Globe in Degrees and Minutes; if it be a large Globe; to find the same Latitude in Geographical Maps.

ON the Globe: bring the Place to the brass Meridian, and count the Degrees from it to the Equator, and it will be the Latitude sought.

IN Geographical Maps: if it be a right-lined one, draw a Line through the Place parallel to the Equator; and the ends of that Line on the Margin show the Latitude.

BUT if it be with Lines, and not any Line passing thro' the Place, fix one Foot of the Compass in the place, and the other in the Pole of the Map; and describe a parallel Circle, which will cut the Degree of Latitude on the Margin that incloseth the Map, or on the Sides of it, if the other Parallels be described from the Pole, and at the same time you'll have it's Distance from the Pole.

PROPOSITION IV.

A Place being given on the Superficies of the Globe, how to place the Globe so as that the wooden Horizon may be the Horizon of the Place.

FIND the Latitude of the Place, and elevate the Pole according to it; and then bring the Place to the brass Meridian, and it will be at the Top of the Globe; and therefore the wooden Horizon will be ninety Degrees from it every way.

PRO-

PROPOSITION V.

The Latitude of a Place is equal to the Elevation of the Pole above the Horizon of that Place; which is thus demonſtrated.

LET C be the Center of the Earth, (*Fig.* 30.) and L the Place brought to the Top of the Globe or Zenith, and P the Pole, H P L Z will be the Meridian, H Z a Diameter of the Horizon, PH the Elevation of the Pole, and Q T the Diameter of the Equator, where the Meridian and Equator cut one another; then P Q will be a Quadrant, or ninety Degrees, P being the Pole of the Equator; and alſo L H will be ninety Degrees, L being the Pole of the Horizon; then L H is equal P Q, and L P being taken from both, what remains, P H, L Q, will be equal.

COROLLARY.

THE Latitude of the Place being given, there is known the Elevation of the Pole.

PROPOSITION VI.

Having the Latitude of one Place, to find all the other Places that have the ſame Latitude.

ON the Globe: bring the Place to a Degree on the braſs Meridian, and placing a Pencil there, turn the Globe, and the Pencil will deſcribe a Circle paſſing thro' all the Places of the ſame Latitude.

AND in the Maps: draw a Line thro' the Place given that ſhall be parallel to the Equator, and it will go thro' all the places of the ſame Latitude.

tude. But if it be a curvilinear Map, describe a Circle (whose Center is the Pole of the Map) that shall pass thro' the Place given; and find, as before, the several Places the Circle passes through. But if not the Place, but the Latitude is given, extend the Compasses from the Pole to that Degree of Latitude on the Side of the Map, and describe a Circle.

PROPOSITION VII.

To find a Meridian Line on a given Plane.

1. THERE are several ways; the easiest is to use a Magnetic Needle which will point North and South: but because in many Places it declines from the North, as we shall show, it will not do it accurately; but if the Declination of the Needle be known, as it is in the chief Places, it may be found accurately enough, drawing first the Meridian, which the Needle shows, and taking the Degrees of the Declination with the Compasses, set them to the East; if the Declination be westward; and, *vice versâ*; then draw a Line from the Point they reach to the Center, and it will be a true Meridian.

THERE is no need of this Pains if you have a Mariner's Compass, wherein there is allowance made for all Declination in that Place for which 'tis made; for they that make the Instrument, put the *Flower de Luce*, which is the Sign of the North not just above the Needle; but so many Degrees from it as the Declination is.

2. BUT the Meridian Line is found better by the Stars. First, when the Sun shines, set up a Pin perpendicular to a Plane at twelve o'Clock, and the Shadow will show the Meridian. But because

becauſe the Hour is not exact enough; this way is not perfectly true.

3. SET a Pin perpendicular to a Plane in the Forenoon, and mark the length of the Shadow; and in the Afternoon mark again, when the Shadow is of the ſame Length, and draw a Line to the two Extremities of the Shadow, and biſect it by a perpendicular Line; which will be a meridian Line.

4. IF the Latitude of the Place be known, and the Sun's Altitude be taken, the meridian Line may be found by the Globe, thus: Draw a Line firſt on a Plane, and make it the diameter of a Circle, and the Line in which the Sun ſeems to be; then the Pole being elevated according to the Latitude; and the Sun's Place in the Ecliptic marked; and a Quadrant applied to the Top of the Globe, with the Sun's Altitude on it marked; then move the Globe and Quadrant both, 'till the Sun's Place and Degrees on the Quadrant meet; then ſee how many Degrees on the wooden Horizon between the braſs Meridian and the Quadrant, and cut off ſo many on the Circle on the Plane, beginning at the end of the Diameter, either to the Eaſt or Weſt, as the Obſervation was made before or after Noon, and draw a Line from the end of the Arch cut off, to the Center, and it will be a meridian Line. But it will be eaſier to obſerve the Line in which the Sun is ſeen either when riſing or ſetting; and bringing the Sun's Place on the Globe to the wooden Horizon, ſee how many Degrees between it and the North or South, and turn the Line on the Plane ſo many Degrees about, and it will be a meridian Line.

PROPOSITION VIII.

To place the Globe so as the brass Meridian may be in the Meridian Line.

FIND a meridian Line on the Plane, under the Globe, and turn it about 'till the brass Meridian be just above it. But this is done easier, if there be a Mariner's Compass under it, which shows the North and South Line.

THUS may Maps be placed also due North and South; of which there is use in Navigation.

PROPOSITION IX.

To find the Latitude of a Place by the Sun or Stars.

THO' the Latitude is on the Earth, yet it cannot be found without the Sun or Stars.

1. OBSERVE how far the Sun is above the Horizon, or it's Distance from the Zenith at twelve o'Clock; then substract the Sun's Distance from the Equator from the Zenith Distance, if the Sun be on the South Side of the Equator; but add it if on the North Side; and you have the Latitude. The Sun's Distance from the Equator, or the Declination, may be had from it's Place in the Ecliptic; or from Tables; or from the Globe, bringing the Place to the Sun under the brass Meridian, then counting how far it is from the Equator.

2. IF the Sun be rising or setting you may find the Latitude by the Globe. Find the Point the Sun is then in, by the Sea-Compass, which Mariners easily do, and find also the same Point on the wooden Horizon; and having the Sun's Place in the Ecliptic, then raise the brass Meridian

dian in the North of the wooden Horizon, or depreſs it 'till the Sun's Place ſet or riſe on that ſame Point in the Horizon; and then ſee how much the Pole is elevated, and it will be the Latitude of the Place.

Note. This Method will not do in the time of the Equinoxes, when the Sun is in the beginning of *Aries* or *Libra*; for then the Sun ſets and riſes in all places in one point, *i. e.* Weſt and Eaſt.

3. TAKE the Altitude of the Sun at twelve o'Clock by the help of the Length of a Style ſet perpendicular, and of it's Shadow, by which may be found the Angle at the Termination of the Shadow in the Triangle (*Fig.* 31.) ABC, that is, the Angle BCA; for as AB is to AC, ſo is the Sine of 90 to the Tangent of the Angle ABC, the Sun's Altitude; from which may be found the Latitude of the Place, as in the firſt Method; and if the obſervation be made at the Equinox, then the Sun's Diſtance from the Zenith is the Latitude.

THUS *Pliny* writes, *Chap.* lxxii *Lib.* 2. that *Rome* was found in Latitude 41 *degr.* 25 *min.* and *Carthage* in Latitude 32 *degr.* 13 *min.*

4. IN the Night-time, when the Stars are ſeen, if we take with an Inſtrument the Altitude of a Star in the Meridian, and know, from Tables, it's Declination; the Latitude may be found as if the Star were the Sun; as in the firſt Method: but if the Star be between the Pole and the Horizon, and the Declination North, the Complement of the Declination is to be added to the firſt Altitude, and it gives the Latitude.

IF the Star be between our Zenith, and the ſouth part of the Horizon; and the Declination North; add the Declination to the Complement of

of the Altitude, and it gives the Latitude, as in the first Method.

5. IF the point in which the Star rises or sets be observed, the Latitude may be found by the celestial Globe as before; supposing the Star to be the Sun.

6. IF you have not a Table of the Declination of the Stars, observe a Star that neither rises nor sets, *i. e.* a circumpolar Star, and observe it's Altitude at the highest and lowest; and take the half of the Difference, and add to the lesser, or substract from the greater, and you have the Latitude.

7. THE Altitude of the Pole-Star, will be the Latitude of the place, if taken when two Degrees seventeen Minutes from the North, eastward or westward; but if it be at the highest, substract two Degrees seventeen Minutes from it's Altitude; if at the lowest on the Meridian, add as much and you have the Latitude.

PROPOSITION X.

Places in the Equator have no Latitude, both Poles being in their Horizon; if at the Pole, the Place is ninety Degrees Latitude, and the Equator is then in the Horizon; and Places between the Pole and the Equator, have a Latitude less than ninety.

THESE are so pain as to need no Proof.

PROPOSITION XI.

If we are at Sea, or Land, and find our Latitude, we may see on the Globe that Parallel of Latitude in which we are.

THIS is also plain.

CHAP. XXIV.

Of the Division of the Earth into Zones, and the Heavenly Appearances in those Zones.

PROPOSITION I.

There arises from the annual or diurnal Motion of the Earth, a division of the Earth's Superficies into five Parts, which we call Zones.

FOR seeing the Sun describes by it's Motion a Line called the Ecliptic, which cuts the Equator in two opposite points, and makes a Declination of twenty three Degrees thirty Minutes; it must be sometimes nearer, and sometimes further from the Equator; and thus changes the Seasons causing Heat, Cold, Rain, Wind, in the Places it passes over.

THE Superficies of the Earth between the two Tropics is called the *Torrid Zone*; and those between the Poles and the polar Circles are the two *Frigid Zones*; and those between the polar Circles and Tropics the two *Temperate Zones*, which make five Zones: that between the two Tropics, being but one, is the *Torrid Zone*.

PROPO-

PROPOSITION II.

The Places whose Latitude is less than twenty three Degrees thirty Minutes lie in the Torrid Zone, *and if just twenty three Degrees thirty Minutes, they are under the Tropics, or at the end of the* Torrid Zone. *Those that have a less Latitude than sixty six Degrees thirty Minutes, and greater than twenty three Degrees thirty Minutes, are in the* Temperate Zone. *Those that are in the Latitude sixty six Degrees thirty Minutes, are at the end of the* Temperate Zone; *and if in a greater Latitude, they are in the* Frigid Zone. *As in Chap.* 23.

ALL this is manifest.

PROPOSITION III.

The Equator passes thro' the Isle of St Thomas *in the great Bay of* Africa *called the* Ethiopic *Sea*; *and thro'* Ethiopia *in the South Part of* Africa; *thro' the* Indian *Ocean*; *thro' the middle of* Sumatra, *or* Taprobane, *and the golden* Chersonesus, *or Peninsula of* Malacca, *and other Islands in the* Indian *Ocean*; *and thro' the* Moluccas, *thro' the* Pacific *Sea, and the beginning of the Province of* Peru; *thro' the Lake* Parime; *and thro' the* Atlantic *Ocean to the Isle of* St Thomas.

THE Equator divides the *Torrid Zone* into two equal Parts; which might be called two *Torrid Zones*, one North, the other South.

IN the *Torrid Zone* lie, 1. a great Part of *Africa*, *Abassia*, the *Indian* Sea, a Part of *Arabia*, *Camboia*, *India*, and the Isles of the *Indian* Sea, *Java*, *Ceylon*, *Peru*, *Mexican-Spain*, a great Part of the

Atlantic Ocean, the Isle of *St Helena*, *Brazil*, and *New Guinea*.

THE Tropic of *Cancer* passes a little beyond Mount *Atlas*, in the western Shore of *Africa*, thro' the Borders of *Libya*, and other Places in the middle of *Africa*, and thro' *Syene* in *Ethiopia*, and goes over the *Red-Sea*, and beyond *Sinai* and *Mecca*, the *Mahometans* Country, and *Arabia the Happy*, and then enters the *Indian* Sea, and touches the Bounds of *Persia*, and goes thro' *Cambaya*, *India*, *Camboia*, or the Bounds of the Kingdom of *Siam*, 'till it comes to the *Pacific* Sea; and having passed that, below the *American Chersonesus* and *California*, it goes to the Kingdom of *Mexico*, and then to the *Atlantic* Ocean, and touches the Shores of the Isle of *Cuba*, and then returns to the West Shore of *Africa*.

THE Tropic of *Capricorn* passes thro' but a few Places of the Earth; most part of it goes over the Sea; first, thro' the South Part, or the *Tongue* of *Africa*, *Monomotapa*, *Madagascar*, in the *Indian* Ocean, *New Guinea*, the *Pacific* Ocean, *Peru*, *Brazil*, and the *Atlantic* Ocean.

IN the North *Temperate Zone* are many Places almost all known and inhabited, *viz.* all *Europe*, *Asia*, (except the golden *Chersonesus*, and the Isles in the *Indian* Sea) and a great part of North *America*, and of the *Atlantic* and *Pacific* Sea.

IN the South *Temperate Zone* are few Places, and those not all known, but chiefly there is Sea there, *viz.* a Part of South *Africa*, of *Monomotapa*, the Cape of *Good-Hope*, a great Part of the *Magellanic*, or South Land, a Part of *Brazil*, *Chili*, the *Magellanic* Streights, and a great Part of the *Atlantic*, *Indian*, and *Pacific* Sea.

THE arctic polar Circle passes almost thro' the middle of *Iceland*, the North Part of *Norway*, thro' the North Ocean, *Lapland*, and the

Russian

Russian Bay, *Samoeids* Country, *Tartary*, North *America*, and *Greenland*.

THE polar antarctic Circle passes thro' the South, or *Magellanic* Land, of which we know nothing.

IN the North *Frigid Zone* are one half of *Iceland*, the North Part of *Norway* and *Lapland*. *Finmarc*, *Samoeida*, *Nova Zembla*, *Greenland*, *Spitzberg*, and some northern Parts of *America* unknown.

IN the South *Frigid Zone* there is either Land or Sea, but we know not which. These are all shown by the Globe or Maps, and are proved by the Tables of Latitude made by Observations.

PROPOSITION IV.

The Places under the Tropics have only the Sun once a Year in their Zenith, and those in the Torrid Zone *twice in the Year, or two Days equally distant from the longest Day; but those beyond the Tropics, and without the* Torrid Zone, *have never the Sun in their Zenith.*

FOR the Sun, being in the first Degree of *Cancer*, goes thro' the Tropic of *Cancer* in the Heavens, under which the same Tropic on the Earth lies; and therefore the Sun goes over them, and the same Way as to the Tropic of *Capricorn*; as will appear in the Globes and Maps.

BUT in the *Torrid Zone* the Sun comes twice over them in a Year. Bring any Place there to the brass Meridian, and applying a Pencil, describe a Circle parallel to the Equator; which will cut the Ecliptic in two Points equally distant from the Tropics, and the Sun in these two Points will then be vertical to the given Place at Mid-day, and on no other Days.

AND laſtly, it can never be vertical to the Places in the *Temperate Zone*, becauſe no parallel deſcribed by the Sun goes over theſe Places; and ſo it is as to the *Frigid Zones.*

PROPOSITION V.

The Sun doth not ſet nor riſe for ſome Days to thoſe in the Frigid Zones; *and the more thoſe Days are, the nearer the Place is to the Pole; ſo that at the Pole it ſets not for half a Year, and riſes not all that time: and thoſe in the very arctic and antarctic Circles have one Day wherein the Sun ſets not, and another wherein it riſes not; but at other times it riſes and ſets.*

TAKE a Place in the *Frigid Zone*, and elevate the Pole according to it's Latitude, and applying a Piece of Chalk, or a Pencil, to the North of the Horizon; that is, next the Pole; deſcribe therewith a Parallel, by turning the Globe round, which will cut the Ecliptic in two Points, into which, and the intermediate Points, when the Sun comes it ſets not: for all the Parallels thro' theſe Points keep above the Horizon in the Rotation of the Globe. And if applied to the oppoſite Notch, and a parallel Circle be deſcribed, it will paſs thro' two Points of the Ecliptic; into which and the intermediate Point, when the Sun comes it riſes not above the Horizon; but it will be otherwiſe if the Place be taken in the other *Frigid Zone.* And ſo as to thoſe Places in the arctic and antarctic Circles, if the Globe be elevated to ſixty ſix Degrees thirty Minutes, and the Globe revolved, the firſt of *Cancer* well then juſt touch the Horizon, and not ſet; and ſo will the firſt of *Capricorn* without riſing above it; but in the other Degrees of the Ecliptic it will ſet and riſe.

PROPO-

PROPOSITION VI.

The Sun rises and sets every Day to all Places in the Temperate *and* Torrid Zones.

TAKE any Place in these Zones, and elevate the Pole to it's Latitude, so as the wooden Horizon may be the Horizon of that Place; then turning the Globe, you'll see all the Points of the Ecliptic rise and set: and so must the Sun in these Points.

PROPOSITION VII.

Having a Place in the Torrid Zone, *to find the two Days in which the Sun is vertical to it.*

BRING the Place to the brass Meridian, and observe the Degree of it's Latitude, and turn the Globe 'till you find the Ecliptic pass under that Degree in two Places, into which when the Sun comes it will be vertical to that Place; then find what time, or Day, of the Year the Sun comes to these two Points, from Tables, or from the wooden Horizon, or by the Method *Chap.* 22.

'TIS also plain in the Universal Maps; for drawing a Line thro' the Place, parallel to the Equator, it will cut the Ecliptic in two places also; from which the two Days may be known.

BUT, without Globes and Maps, you may find the Latitude of the Place, in Degrees, and look in the Table of Declination for the same Number of Degrees of Declination, and you'll have the two Days answering thereto.

Note. The Sun's Center, which is sixteen Degrees from it's Circumference, will be a few Days sooner, or later, vertical to the Place, than the Cir-

cumference, in it's North or South Point at Mid-day.

PROPOSITION VIII.

A Place being given in the Frigid Zone, *to determine the Days in which the Sun doth not ſet there, nor riſe and when thoſe Days begin and end.*

ON the Globe. Let the Place be brought to the Meridian, and the Pole elevated to it's Latitude; then, turning the Globe round, obſerve the two Points in the Ecliptic which do not ſet, or go under the Horizon; the firſt, that is next to *Aries*, ſhows the firſt Day of it's not ſetting, and that next *Libra* the Day when it begins to riſe, and the two Days in which the Sun is in thoſe Points the Sun will only touch the Horizon, and it's Center will be a little above it; and thus the Days are found in which the Sun will be under the Horizon in the oppoſite Part of the Year.

THIS may be done eaſier by the Globe, tho' the reaſon of it is not ſo obvious. Find the Complement of the Latitude of the Place, and count ſo many Degrees from the Equator, and mark what Points of the Ecliptic come under that Degree on the Meridian, and they will be found to be two points into which, or the intermediate Point, when the Sun comes, it will not ſet: and ſo you have an Arch, at the South, which ſhows how long 'tis under the Horizon.

AFTER the ſame in the Maps; draw a Line thro' the Degree, that is as far from the Equator as the Place is from the Pole, and you'll ſee what Point it cuts in the Ecliptic; in and between which when the Sun comes it doth not ſet: and in the South part you ſee how long 'tis under the Horizon.

IF the Latitude of the Place be known, find the ſame Degree and Minute in the Table of Declination, and againſt it you'll have the Day in which it begins and ends the not ſetting; and other two Days that have the ſame South Declination in which it begins and ends the not riſing; the firſt will be between the twenty firſt of *June* and the firſt of *March*; the other between the twenty firſt of *June* and the twenty firſt of *September*; and one of the laſt between the twenty firſt of *September* and twenty firſt of *December*; the other between that, and the twenty firſt of *March*.

THIS is to be underſtood of the Sun's Center which is ſixteen Minutes above and below the Limb.

PROPOSITION IX.

Having the Day of the Year, to find thoſe Places in which the Sun will then be vertical.

FROM the given Day, find the Sun's Place in the Ecliptic as in *Chap.* 22.

BRING the Sun's Place in the Ecliptic under the Meridian, and mark the Degeee above it; and turning the Globe, obſerve all the Places that paſs under that Degree will have the Sun vertical one after another: and in the Maps find the Sun's Place in the Ecliptic, and draw a Line parallel to the Equator, either ſtraight or curve, as the Map is, and all the Places it paſſes over are thoſe ſought.

BY the Table of Declination find the Degree of Latitude of thoſe Places, or, which is the ſame the Degree of Declination that Day; which being found, you'll have the Places by drawing a Line thro' thoſe Degrees.

PROPOSITION X.

Having the Day of the Year, to find those Places in which the Sun begins then not to set and not to rise.

THE given Day must be between the twenty first of *March* and twenty first of *June*, or twenty first of *September* and twenty first of *December*.

FIND first the Sun's Place for that Day, which bring to the Meridian; and as many Degrees as are between it and the Equator, count so many from the Pole towards the Equator; and draw a parallel Circle at that Distance from the Pole: all the Places within it will show the first, *i. e.* the Sun's not setting there; and the like being drawn as near the other Pole, will include the Places where it does not rise; and the Places under the two Parallels show where these two Changes begin. Then,

TO show the Truth of it; elevate the Pole according to the Latitude of any of the Places; and it will appear when the Sun's Place in the Ecliptic begins not to set; and how long it continues so; and when it begins not to rise in the South Part. The same may be done by the Maps, taking the Declination of the Sun, which will reach from the Pole to the Parallel in which the Sun begins not to set: and so likewise at the South.

AND by the Table of Declination you have the Latitude of the Places sought for.

PROPOSITION XI.

To calculate the Breadth and Quantity of each Zone *in Miles, or any known Measure.*

THE

THE Breadth of the *Torrid Zone* is 47 Degr. *i. e.* 23 Degr. 30 Min. on each side of the Equator. The Breadth of each *Temperate Zone* is 86 Degr. and of both *Frigid Zones* 27 Degr. which Degrees, if turned to Miles, counting each Degree 15 *German* Miles, the Breadth of the *Torrid Zone* will be 705 Miles. And one of the *Temperate* 645, and one of *Frigid* 352 ½. And the Superficies of each is known by this Proportion from Geometry; as the Sine of 90 Degr. 1000000 is to the Sine of 23 Degr. 30 Min. *viz* 39875; so is half the Superficies of the Earth found in *Chap.* 4. to be 4639090 square Miles to the Superficies of half the *Torrid Zone*, *i. e.* 1849837 square Miles; and therefore the Superficies of the whole *Torrid Zone* is 3699674 Miles.

THEN as the whole Sine 100000 to the Difference of the Sines of 23 Degr. 30 Min. and 66 Degr. 30 Min. 51831; so is the half Superficies of the Earth, or 4639090 square Miles, to the Superficies of one of the *Temperate Zones* 2404487 square Miles. If therefore you substract the Superficies of half the *Torrid Zone*, and that of the *Temperate Zone*, from half the Superficies of the Earth, there remains the Superficies of one of the *Frigid Zones* 384766 square Miles. Some Astronomers are of Opinion, that the Declination of the Ecliptic is not always the same; and therefore the Bigness of the Zones is not always the same; but the Difference is small: and *Tycho* doubted if there was any. We need not mind it here.

WE might have treated of the different Seasons in different Places; but because there are some things in the following Chapter that will help us to make a better Judgment thereof, I thought it best to defer it.

CHAP.

CHAP. XXV.

Of the Length of the Day in different Places of the Earth, and the Division of the Earth into Climates, which arise from thence.

PROPOSITION I.

The Day and Nights are of the same Length twice in the Year in all Places.

THESE Days are when the Sun is in the Equator, *i. e.* in the first of *Aries* and *Libra*, on the twenty first of *March*, and twenty first of *September*, according to the *Gregorian* Calendar; which Days have twelve Hours Day, and twelve Hours Night, in all Places, counting the time the Sun is above the Horizon for a Day.

TAKE any Place on the Globe, and elevate it according to its Latitude, or bring the Place to the Zenith; then bring the Sun's Place to the Horizon in the East, and the Index of the horary Circle to twelve, and turn the Globe; you will find it will describe twelve Hours, while the Sun's Place is going to the Horizon in the West: it appears further from the Horizon's cutting the Equator into two equal Parts. We might show it the same way, whatever Place of the Earth be chosen. And the two Poles do those two Days neither rise nor set, and they have there Night and Day at once; in other Places it turns from Day to Night in an Instant, but there they last together for a whole Revolution; the one half of the Sun being above, and

and the other below the Horizon. On the twenty first of *March* begins a Day of six Months, and on the twenty first of *September* a Night as long; and we may say, 'tis both Day and Night for twelve Hours at the Pole. There are other things peculiar to that Place.

1. THE Sun only rises and sets there once in a Year, it rises the twenty first of *March*, and sets the twenty first of *September*.

2. THEY have no Mid-day and Mid-night at a set Time; their Mid-day being at all Times for six Months, and the other six 'tis always Midnight.

3. NO fix'd Stars rise, and none set, but some are always under, others always above; the former of which being never seen by the Inhabitants, if any there, which is not likely; the latter always seen for six Months if the Weather be clear when the Sun is under the Horizon.

4. THE Stars and the Sun keep almost the same Altitude all Day.

5. NO Wind can be called there, northerly they being all from the South; and in the other, the South Pole, they are all northerly.

6. IF the Sun and Stars move not according to *Copernicus*, but the Earth, and the Eye be a Point placed in the Pole, all the Stars, and the Sun and Moon, would appear immoveable in the same Place.

PROPOSITION II.

In Places under the Equator the Days and Nights are always equal; and at the Poles there is but one Day and Night in the Year; tho' the Day at the North Pole is longer than at the South Pole.

TAKE

TAKE any Place on the Globe under the Equator, and any Day of the Year, and mark the Sun's Place that Day, and bring the Place to the Zenith, the Poles being in the Horizon; and it will appear, that that Place, in a Revolution of the Globe, will be as long above as under the Horizon, ſuppoſing it's apparent Motion equal, as indeed it is. And as to the other Part of the Propoſition; bring the Pole to the Zenith, the one half of the Ecliptic will be above, the other below the Horizon, but the Sun will be longer above than below, for it really moves in an *Ellipſis* whoſe *Focus* is out of it's Center; or the Earth does ſo, which makes the ſame Appearance: there are one hundred eighty ſeven Days it continues above, and one hundred ſeventy eight below; which makes the Day about nine Days longer than the Night.

PROPOSITION III.

There are no Days equal except two in the Places between the Equator and the Pole.

TAKE any Place, and elevate the Pole according to it's Latitude, and taking any Day, except thoſe two of the Equinoxes, and mark the Sun's Place in the Ecliptic for that Day; turn the Globe and you will ſee the Mark will be longer above than below the Horizon, if the Day be between the twenty firſt of *March*, and twenty firſt of *September*; but if not, it will be longer below the Horizon: and the Difference will be the greater, the further the Sun is from the Equator.

OR bringing the Sun's Place to the Eaſt Horizon, and the Hour Hand to twelve, you will ſee, in turning the Globe, the Hours of the Day 'till the Sun ſet in the Weſt; and it's continuance under the Horizon.

PROPOSITION IV.

A Place being given, and it's Latitude, to find the Length of the Day at any Time.

FIND the Sun's Place at that time in the Ecliptic, and elevate the Pole to the Latitude of the Place, bring the Sun's Place to the East Horizon, and the Hour Hand to twelve; you will see how many Hours the Sun's Place will take to come to the West Horizon; and substract them from twenty four, and you have the Length of the Day.

PROPOSITION V.

In all Places between the Equator and North Pole, the Day is longest when the Sun is in Cancer, *and shortest when in* Capricorn; *but in those Places between the Equator, and the South Pole the contrary happens; that is, when the Sun is in* Cancer, *the Days are shortest, and when in* Capricorn *longest.*

TAKE a Place at Pleasure, and elevate the Pole according to it's Latitude; find, by the preceding Proposition, the Number of Hours in the Day, when the Sun is in the first of *Cancer*; and find also the Number of Hours for another Part of the Ecliptic, which will be found less, whatever other Part of the Ecliptic be taken.

THE same way it may be shown, that the Day is shortest when the Sun is in the first of *Capricorn.* And the same Method may be taken when the Sun is on the other Side of the Equator.

COROL-

COROLLARY.

A Place being given, or it's Latitude, to find the Length of the longest Day: find, as before, the first of *Cancer*, and find the Hours it continues above the Horizon, by the preceding Proposition.

PROPOSITION VI.

The Days increase continually in the northern Places while the Sun moves from the first of Capricorn *to the first of* Cancer, i. e. *from the twenty first of* December, *to the twenty first of* June; *but the contrary way in South Places,* i. e. *when it moves from* Cancer *to* Capricorn, *or from the twenty first of* June, *to the twenty first of* December.

TAKE any Place on the North Side of the Equator, and elevate the Pole for that Latitude; and take two or more Places in the Ecliptic, and you will find that which is nearest the first of *Cancer* keeps longest above the Equator: and the same will happen as to those Places on the South Side of the Equator; if the South Pole were elevated to the Latitude, those Degrees nearest the first of *Capricorn* would be longer above the Horizon.

PROPOSITION VII.

If one Place be further from the Equator than another, the difference of the longest and shortest Day, and between Day and Night, will be greater there; so as that the Places near the Equator have the longest and shortest Day, and Days and Nights but little different. They at the North Tropic have only two hours Difference between the longest and shortest Day; and their Days and Nights nearly equal.

THIS

THIS will easily appear by taking two Places, one more northerly than the other, and finding the Length of the Day, at two Times of the Year; for one Place, and for the same Times in the other Place; and also the Difference of the Day and Night at that time, and you will find the Difference greatest in the Place of greater Latitude, both as to the Day and Night, and the longest and shortest Day.

PROPOSITION VIII.

All the Places in the same Parallel have all their Days equal, and therefore their longest Day equal.

FIRST elevate the Pole according to the Latitude of any Parallel; then take two Places in that Parallel, and bring the one to the Meridian, and observe how much of it is below, and how much under the Horizon; then bring the other to the Meridian, and observe the same, and you will find the Difference the same in both. This might be also shown by the horary Circle.

FROM these Things may be easily understood the Division of the Earth into Climates.

A Climate is the Space included by two Parallels, between the Pole and the Equator, into which when the Sun comes, there is the Difference of half an Hour, as to the Length of the Day; in which we may observe the beginning of Climate in the Parallel nearest the Equator, and the middle when the Day becomes a Quarter longer, and the end in the Parallel from the Equator, which is the beginning of the next Climate.

PROPOSITION IX.

If we take several Places, whose Parallels are equally distant, their longest Days will not exceed one another

ther equally; the Difference being greatest where they are most distant from the Equator.

TAKE first one Parallel, and raise the Pole to that Latitude, and observe the Continuance of the first of *Cancer* above the Horizon; then raise the Pole to the Latitude of another Parallel that is ten Degrees from it, and observe the Continuance above the Horizon there, and so for another thirty Degrees, and forty Degrees; the Continuance of the first of *Cancer* above the Horizon, will not exceed one another equally.

AND what is said of the longest Day, or the first of *Cancer*, will hold as to any other Day or Degree of the Ecliptic.

PROPOSITION X.

If in several Parallels the longest Days exceed one another equally, these Parallels will not be equidistant; and those further from the Equator will be nearer together.

THIS may be shown by the former; for if they were equidistant, the Days would not equally exceed one another as is supposed.

PROPOSITION XI.

Having the Length of the longest Day in any Place, to find the Latitude of that Place.

BRING the first of *Cancer* to the Meridian, and the Index to twelve, and turning the Globe 'till the Index point to the Hour, as far distant from twelve as the Day is long; and mark the Point of the Tropic under the Meridian, then bring the first of *Cancer* to the East Horizon, and elevate the Globe

Globe 'till you mark the Tropic in the West Side of the Horizon, and the first of *Cancer* in the East Side, and the Degrees of Elevation show the Latitude.

THIS Proposition may be made more general thus; having the Length of the Day in any Place, to find it's Latitude. This may be solved the same way, only for the Tropic take a Parallel that goes thro' the Sun's Place that Day.

COROLLARY.

THE Latitude of the Parallels of each Climate may be thus easily found; for Example, in the end of the first Climate, the Length of the Day is twelve Hours and a half, and of the second thirteen Hours, *&c.*

PROPOSITION XII.

Having any Number of Days less than half a year; to find the Latitude of that Parallel where the Sun shines so long to them, and where 'tis hid from them so long.

TAKE half the Number of Days, and count so many Degrees from the first of *Cancer* on the Ecliptic, and mark where they end, and count from the Mark to the Pole, and you have the Latitude of that Place where the Days and Nights will be of such a Number of Days.

FOR if you raise the Globe to the Latitude found, you will see that Point in the Ecliptic, dip at the North Part of the Horizon; and all the Points between that and *Cancer*, and as far beyond it, will keep above the Horizon; and so the Sun in them doth not set.

COROLLARY.

THUS 'tis easy to find the Latitude, of the Climates in the *Frigid Zones*, where the longest Day increases by some Days.

PROPOSITION XIII.

To make a Table of Climates.

THAT is, to find the Latitude, and the longest Day at the beginning, middle, and end, of each Climate; and the distance of the Parallels. First add still to twelve a Quarter of an Hour; and you have the increase of the Day for that Climate; then from that Length of Day find the Latitude by *Prop.* 11. and, for the Distance of the Parallels, substract the Latitude at the end of the one Parallel, from that at the end of the next, more northerly. The same way the middle of the Climate is found by adding a Quarter to twelve; and find the Latitude for that by *Prop.* 11. We here add a Table of Climates and Parallels.

A Table of Climates and Parallels.

Climates	*Parallels*	*Longest Day*		*Latitude*		*Interval*	
		Hours	*Min.*	*Degr.*	*Min.*		
	Begin.	12	0				
1	Middle	12	15	4	15	4	15
	End	12	30	8	25	8	25
2	Middle	12	45	12	30		
	End	13	0	16	25	8	
3	Middle	13	15	20	15		
	End	13	30	23	50	7	25
4	Middle	13	45	27	40		
	End	14	0	30	20	6	30

Climates

Climates	*Parallels*	*Longest Day*		*Latitude*		*Interval*	
		Hours	*Min.*	*Degr.*	*Min.*		
5	Middle	14	15	33	40		
	End	14	30	36	28	6	8
6	Middle	14	45	39	2		
	End	15	0	41	22	4	54
7	Middle	15	15	43	32		
	End	15	30	45	29	4	7
8	Middle	15	45	47	20		
	End	16	0	49	1	3	32
9	Middle	16	15	50	53		
	End	16	30	51	58	2	57
10	Middle	16	45	53	17		
	End	17	0	54	27	2	29
11	M ddle	17	15	55	34		
	End	17	30	56	37	2	10
12	Middle	17	45	57	32		
	End	18	0	58	29		
13	Middle	18	15	59	14		
	End	18	30	59	58		
14	Middle	18	45	60	40		
	End	19	0	61	18		
15	Middle	19	15	61	55		
	End	19	30	62	25		
16	Middle	19	45	62	54		
	End	20	0	63	22		
17	Middle	20	15	63	40		
	End	20	30	64	6		
18	Middle	20	45	64	30		
	End	21	0	64	49		
19	Middle	21	15	65	6		
	End	21	30	65	21		
20	Middle	21	45	65	35		
	End	22	0	65	47		

Climates	*Parallels*	*Longest Day*		*Latitude*		*Interval*
		Hours	*Min.*	*Degr.*	*Min.*	
21	Middle	22	15	65	57	
	End	22	30	66	6	
22	Middle	22	45	66	14	
	End	23	0	66	20	
23	Middle	23	15	66	25	
	End	23	30	66	28	
24	Middle	23	45	66	30	
	End	24	0	66	31	

THEY uſe not to carry the Table further; for, in the Places following, the longeſt Day increaſes not by Hours, but by whole Days; and the following Canon will ſhew the Latitude where it increaſes even by Months.

Months	1		2		3		4		5	6
	D.	*M.*								
Latitude	67	30	69	30	73	20	78	20	84	90

PROPOSITION XIV.

To explain the Method of other Geographers in enumerating the Climates, and making the Table.

THE antient Geographers, eſpecially the *Greeks*, thought there was but a ſmall Portion of the Earth inhabited; thinking the northern Places, and *Torrid Zone*, could not be inhabited; and therefore they divided only the Part they knew into Climates, and counted only ſix of them from the Equator to the Arctic Pole, which they named from ſome remarkable Place in their Middle.

THE

THE first was thro' the Isle of *Meroe*, in *Africa*, or the City so called, which is surrounded with the *Nile*.

THE second thro' *Syene*, a City in *Egypt*.

THE third thro' *Alexandria*, a Sea-Port in *Egypt*.

THE fourth thro' the Island *Rhodes*, in the *Mediterranean*.

THE fifth thro' the *Hellespont*, others thro' *Rome*.

THE sixth thro' the *Borysthenes*, a famous River in *European Sarmatia*.

THE seventh thro' the *Riphœan* Mountains of *Sarmatia*.

THEY did not count any Climates to the South, which was unknown, and which many thought was all Sea; but others after them thinking that unlikely; they did also count Climates on the other Side of the Equator; not from remarkable Places, for they knew none there; but called them, as the North Climates are, with the Proposition *Anti* before them; as the Climates against *Meroe*, or *Syene*, &c.

AND when they understood that more Parts were inhabited, they made more Climates; some named the eighth Climate from the Lake of *Mœotis*, the ninth from the *Baltic* Sea, &c. which Names tho' they are not necessary in the Construction of the Table, yet may be added to our Table where we place the Number of Climates; thus we shall better remember the Climates, and the Places in each Climate, and may compare the Degrees of Heat and Cold in them: which we chuse rather to leave to the Industry of the Readers, that they may be the better acquainted with the Globe.

MOREOVER, they did not begin at the Equator as we do, but at the Place where the longest Day is twelve Hours three Quarters, and

ſo their firſt is the ſecond in ours, and their ſecond our third; for they reckoned that the Places under nine Degrees of Latitude could not be inhabited for the Heat there; but the contrary being found, we could not aſſent to their Method. *Ptolemy* begins the firſt Climate where the longeſt Day is twelve Hours and a Quarter, or the Latitude four Degrees fifteen Minutes. 'Tis no great Matter, yet 'tis better to begin at the Equator, that all Places may be in ſome Climate.

PROPOSITION XV.

To ſhow the Uſe of the Table of Climates.

1. HAVING the Latitude of a Place, to know it's longeſt Day, and it's Climates. Find the Latitude in the Table, and over againſt it you have the longeſt Day, the Climate, and Parallel; if the Latitude is not in the Table, take the next above, and below it.

2. HAVING the Length of the longeſt Day in any place, to know the Latitude and Climate in that place. Find the longeſt Day, and againſt it you have both.

3. HAVING the Climate, to find the longeſt Day. This is eaſily found in the Table.

CHAP.

CHAP. XXVI.

Of Light, Heat, Cold, and Rain in the different Zones, and other Properties belong to the several Zones.

PROPOSITION I.

The Causes that most contribute to make Light, Heat, Cold, Rain, and other Meteors, and to preserve them in several Zones, and the neighbouring Places, are:

1. THE greater or less Obliquity, or Perpendicularity of the Rays that come on the Place. The last of which make the greatest Heat, and the other two make more or less Heat in proportion to their Obliquity.

2. THE Continuance of the Sun above the Horizon of the Place.

3. THE greater or less Depression of the Sun under the Horizon in the Night; which causes more or less Light, Heat, Rain, thick Clouds, *&c.* From this comes more or less Twilight.

4. THE Continuance of the Moon, for more or less time above or under the Horizon; and it's greater or less Elevation above it, or Depression under it.

5. THE same may be said of the fixed Stars, especially the more remarkable; and of the five Planets, *Saturn*, *Jupiter*, *Mars*, *Venus*, *Mercury*; for they all cause some small Light and Heat in the

Air, and change the Air various ways, and excite Vapours in it, as Aſtrologers tell us.

6. THE Kinds of the Earth that are in ſeveral Places; for where the Earth is rocky or ſtony, there the Air is for the moſt part colder than where 'tis fat and ſulphureous, and not ſo fertile; or where there is much Sand and no Rivers there is much Heat and Drought.

7. ADJACENT Seas or Lakes; from thence come a great many moiſt Vapours into the Air; and the Rays are not ſo ſtrongly reflected from the Sea as from the Land.

8. THE Situation of Places; for the Sun influences the Mountains and Vallies differently, and the Rays are kept from the Plains oftentimes by the Mountains, which do alſo in ſome manner draw the Vapours to them, as we ſaid, *Chap.* 20. Whence 'tis the Mountains change the Seaſons of the neighbouring Places; cauſing Heat, Rain, *&c.* which would not be if the Mountains were not there.

9. THE Winds, eſpecially the general and ſtated ones; thus the ſtated eaſterly Winds temper the Heat of the *Dog-Days*, and the general Wind in the *Torrid Zone*, eſpecially the Eaſt Winds in *Braſil* cauſe a moderate Heat there: whilſt there is a vehement Heat in the Weſt of *Africa*; for in theſe Places the general Wind is not ſo ſenſible. The North Winds are cold and dry. The South Winds are hot and moiſt with us.

10. THE Clouds and Rain leſſen the Light and Heat.

THESE are, I ſuppoſe, all the Cauſes of the Changes that happen as to Light, Heat, *&c.* either in the ſame, or different Places, at different, or the ſame times.

PROPOSITION II.

How the Seasons of the Year, as Spring, Summer, Autumn, and Winter are to be defined.

ALTHO' we are not, in treating of the Sciences, to dispute about the Definitions of Things; yet, because the Signification of some Words is dubious; we must explain them here, to avoid Confusion, and that Students may not be entangled and deceived with different Meanings.

THE Question includes two Difficulties; 1. Whether the Seasons are determined by the Sun's Entrance into, and continuing in, certain Signs of the Ecliptic, as Astronomers generally suppose, calling it Spring when the Sun enters the first of *Aries*, which continues 'till it enters the first of *Cancer*, and making it Summer 'till the Sun moves from that to the first of *Libra*; and Autumn 'till it come to the first of *Capricorn*; and Winter 'till it come to the first of *Aries* again.

'TIS evident that these Definitions are not true in all Places, but only in those to the North of the Equator; for in the South Places they have Spring while the Sun is between the first of *Libra*, and the first of *Capricorn*, and Summer from that to the first of *Aries*; and so on the contrary to the former: and one may think the Seasons cannot be explained in a Sense agreeable to all Places, and yet they may, and ought to be. Moreover, the Definitions above do not agree to Places in the *Torrid Zone*; for when the Sun passes over them it must be allowed to be Summer there (except some other Cause alter it); with respect to the Heavens, and in Places on the Equator, it ought not to be either Spring or Autumn when the Sun is past the first of *Aries*, but Summer, for then the Sun is passing over

over them, and ſo making the greateſt Heat to them: nor can that Summer be transferred to the firſt of *Cancer* or *Capricorn*. And the ſame may be ſaid of Places between the Equator and Tropics, becauſe the Sun paſſes over them alſo before it comes to the firſt of *Cancer* or *Capricorn*, and ſo makes Summer firſt. For it muſt be known, that tho' Definitions are arbitary, yet all agree in making the Summer to be cauſed by Heat, and the Winter by Cold, or leſs Heat; and Definitions muſt be ſo framed, as to agree in part with theſe Notions, or not to be repugnant to them; and there is the ſame Difficulty as to Spring and Autumn in the *Torrid Zone*; whilſt there ſeems to be none at all, eſpecially at the Equator.

THE ſecond Difficulty which made the Queſtion be propoſed is, *whether the Seaſons are to be determined from the Degree of Heat and Cold, or from the Sun's approach, or withdrawing?* for the common Notion of the *Europeans* of the Seaſons includes them both, eſpecially the Cold and Heat, tho' Aſtronomers have moſt regard to the Sun's Place in the Ecliptic. Moreover, 'tis found in many Places in the *Torrid Zone*, that the Seaſons do not anſwer the Sun's coming to them, or going from them, but that they find it Winter (abounding not indeed with Cold, but with Rains and Storms) when it ſhould be Summer, by the Sun's being nearly above them; and on the contrary, they find it Summer when the Sun goes from them, and they ſhould rather have Winter; of which ſtrange thing we ſhall give Examples afterwards. And therefore they make their Summer to conſiſt in a clear Sky; and their Winter in wet Weather, with a little Cold. And therefore the Notions of the Seaſons differ much according to the Places.

AFTER

AFTER considering these Difficulties, I am of Opinion; 1. seeing in several Places of the *Torrid Zone*, as was said in the second Difficulty, and also in some places in the *Temperate Zone*, Heat and Cold have no regard to the Sun's Motion; nor are we to think that Heat and Cold makes the Seasons, except we distinguish between Seasons of the Heavens and of the Earth; which Words we must use for want of better: hence the terrestrial Summer Season of a Place, is the Time of Year when there is greatest Heat there; but the celestial Summer is the Time when one might expect the greatest Heat from the Sun's nearness; and the like may be said of the Winter Season: and tho' in several Places the celestial and terrestrial Summer and Winter happen at one Time of the Year; yet in some Places of the *Torrid Zone* they are in different Times of the Year, as shall be showed hereafter. And the same is to be said as to the celestial and terrestrial Spring and Autumn.

2. SEEING there are but few Places where the terrestrial Summer and Winter differ from the celestial, as to the time of Year, they happening in most Places at the same time of the Year; therefore the celestial Summer may be called simply the Summer, and so the terrestrial Spring, the Spring, *&c.* and when we would speak of the terrestrial Summer or Winter we shall call them Terrestrial, to distinguish them from those absolutely called Summer and Winter, when the Celestial and Terrestrial agree.

THE celestial Summer of a Place is when the Sun comes nearest to it's Zenith; and Winter when furthest from it; and Spring is between the end of Winter, and beginning of Summer; and Autumn between the end of Summer and beginning of Winter. And these four Seasons may be thus understood in all Places.

PROPO-

PROPOSITION III.

The celestial Summer of those Places between the North Tropic, and the North Pole, begins when the Sun enters the first of Cancer, *on the twenty first of* June, *and ends, when it enters the first of* Libra, *on the twenty first of* September; *and at the same time in all those Places. And 'tis Autumn with them when the Sun goes from the first of* Libra *to the first of* Capricorn, *and Winter while 'tis between the first of* Capricorn, *and the first of* Aries.

THE Truth of this Proposition appears from the foresaid Definitions, and may be easily shown on the Globe and Maps; for the Sun is least distant from the Zenith when in the Tropic of *Cancer*; and is at a mean Distance when between the first of *Libra* and *Capricorn*.

THE Summer Places between the South Tropic and the Pole, which takes in the *Temperate* and the *Frigid Zone*, begins when the Sun enters the first of *Capricorn*, and ends when it enters the first of *Aries*; and their Autumn is between the first of *Aries*, and the first of *Cancer*; and the Winter between that, and the first of *Libra*; and between that, and *Capricorn* is their Spring.

THIS may be shown the same way as the former.

THE Seasons in the *Torrid Zone* do not begin in all Places at the same time. 1. Those under the Equator have this peculiar to them, that they have two Summers, two Winters, and as many Springs and Autumns, and that each Year; so that between the twenty first of *March*, and the twenty first of *September* they have, or should have by the Sun's Course all the four Seasons; and the same

same again between the twenty first of *September*, and the twenty first of *March*.

ONE Summer is between the first of *Aries*, and the second of *Taurus*, or Tenth of *March*, and Eleventh of *April*.

AUTUMN between the second of *Taurus*, and the first of *Cancer*; or Eleventh of *April*, and Tenth of *June*.

WINTER between the first of *Cancer*, and the twenty eighth of *Leo* or the Tenth of *June*, and Tenth of *August*.

SPRING between the twenty eighth of *Leo*, and first of *Libra*; or Tenth of *August*, and Twelfth of *September*.

AND the same Seasons return when the Sun is in the opposite Places of the Ecliptic; which is easily demonstrated on the Globe, according to the foresaid Definitions, or the Sun's Distance from the Zenith. But as to the terrestrial Seasons, they are different in several Places under the Equator.

2. THE Places in the North *Torrid Zone* have the end of Autumn, and beginning of Winter at the same time on the twenty first of *December*; but the beginning and end of the other Seasons of Summer and Spring, and also the beginning of Autumn, are not at the same time, but are on different Days in different Places; for the end of Autumn, and beginning of Winter, is there when the Sun is furthest from the Zenith, when in the Meridian, which happens in the first Degree of *Capricorn*. The other part is also plain, for if the Places have different Latitudes, the Sun will be in their Zenith on different Days; that is, their Summer begins at different Times, and will have a mean Distance from the Zenith at different Times, and so their Summer will end, and Autumn begin at different Times. And in the same way, their Winter will end, and Spring begin at different

different times; becauſe the mean Diſtance from their Zenith will be different; tho' it will, in all Places, begin between the Tenth of *December*, and the Tenth of *March*.

3. THE Places in the South *Torrid Zone* have the end of Autumn, and beginning of Winter at the ſame Time *i. e.* the Tenth of June; but the beginning of Summer and Spring, and the beginning of Autumn, are not at the ſame Time, but different in different Places; yet ſo as the Summer there always falls between the Tenth of *September*, and the Tenth of *December*; and the end of Autumn, and beginning of Summer, between the Tenth of *March*, and the Tenth of *June*; and the beginning of Spring, and end of Winter, between the Tenth of *June*, and the Tenth of *September*. This may be proved as the former was; for the Sun, being in the firſt of *Cancer*, is then at it's greateſt Diſtance from thence; and then it's Winter in them all; and the Sun being vertical to them in different times, their Summer, and conſequently Autumn and Spring, are at different times.

4. THOSE Places between the Equator and the eighth Degree of North, or South, Latitude have ſomething peculiar; *viz.* the Sun, by approaching to, and withdrawing from their Zenith, makes two Summers, two Springs, and but one Autumn, and one Winter in a perverted order, thus; Spring, Summer, Spring, Summer, Autumn, Winter.

THE Cauſe of this Paradox is this: ſuppoſe a Place in the eighth Degree of North Latitude, the Sun is vertical to it in the Tenth Degree of *Aries*, and then Summer and Winter will be to them when the Sun is in the firſt of *Capricorn*, which is twenty ſeven Degrees thirty Minutes from the Parallel of the eighth Degree of North

Latitude; and the Sun will have a mean diſtance when 'tis thirteen Degrees forty five Minutes from them; which happens four times in a Year; 1. when in the third of *Gemini*, then the Spring begins, becauſe the Sun begins then nearly to approach to the Zenith of the Place, where it will be Summer again in the twentieth of *Virgo*; and when it comes to the twenty fifth of *Libra*, 'tis at a mean diſtance again, and then begins Autumn; the Sun withdrawing from them; and at the firſt of *Capricorn* it is Winter; and at five Degrees of *Piſces* 'tis at a mean Diſtance again, and then begins Spring, for the Sun is approaching to them: and the ſame happens in Places under the eighth Degree of South Latitude.

BUT if the Place be above eight Degrees Latitude, then it doth not hold good; for the Sun in *Cancer*, or *Capricorn*, is here a leſs Diſtance than a Mean: for if in the ninth Degree of North Latitude the greateſt Diſtance will be at the firſt of *Capricorn*, which is thirty two Degrees of Declination North and South; and the Mean ſixteen, which is more than the firſt of *Cancer*'s Diſtance, which is but fourteen Degrees thirty Minutes; therefore Summer will then laſt 'till the Sun be ſixteen Degrees from their Zenith, which is not 'till the Sun comes to the twenty fourth Degree of *Libra*, about the Sixth of *October*.

THERE ſeem to be here ſome new Difficulties; 1. That it cannot be Summer with them when the Sun is in *Cancer*, *Leo*, *Virgo*, for the Sun is in them both going from and to the Zenith; but that 'tis Summer only in the going from the Zenith. I anſwer, that Summer conſiſts in it's going back from the Zenith to a mean Diſtance, which it never does 'till it come to the twenty fourth of *Libra*, when the Summer muſt end.

2. IN

2. IN Places under the eighth Degree of Latitude, or in the fourth, as was ſuppoſed, the Spring could not begin when the Sun is in the third of *Gemini*, for then 'tis going further from the Zenith; but it goes only one Degree further, and therefore we ſaid it was nearly Spring, and we cannot make a fifth Seaſon for that ſmall Matter.

OTHERS may think we ſhould not put Spring between two Summers, but count it all Summer, while the Sun is at leſs than a mean Diſtance from the Zenith. And tho' it go a Degree further, yet that will not cool the Air ſenſibly, but rather, by it's Continuance, increaſe it; tho' we ſhall not diſpute that matter, only think the Method laid down is beſt. But enough, or too much, of this (*a*).

(*a*) Mr *Ditton* has given a geometrical and eaſier Demonſtration of this Paradox. By the Definitions explained under *Prop.* 2. Each of thoſe Places ſhould be ſo ſituated, that two Points may be taken in its Meridian, one lying to the North, the other at an equal Diſtance to the South; the Diſtance whereof ſuppoſe from the Vertex equal to the mean Diſtance of the Sun from the ſame. Let now AB be the Equator, (*Fig.* 32.) CD and EF the Tropics, and CAE, FBD, the Meridian of the Place, and a place therein *b*, as remote as poſſible from the Equator to the North. The North Point therefore is C, whoſe Diſtance *b*C is equal to the mean Diſtance of the Sun, or half *b*E (for becauſe there is no leaſt Diſtance of the Sun, therefore the mean Diſtance is half the greater) that is, to a third of CE, or $4\frac{7}{3}=\frac{2}{5}$ 15. Therefote as CA is $23\frac{1}{2}$, A*b* will be nearly eight Degrees; and therefore all theſe Places are nearly within eight Degrees of the Equator. But the Sun proceeding in it's annual Motion from E to C, and then again returning to E, produces the abovementioned Seaſons in this Order. When in the Point E, where the Diſtance is greateſt from the Place *b*, it begins Winter, in *d* the Spring (*viz.* *bd* = *b*C) in *b* the Summer, in C the ſecond Spring, in *b* the ſecond Summer, and in *d* the Autumn.

PRO-

PROPOSITION IV.

A Place being given in the Torrid Zone, *to find the Days when the Summer, Autumn, Spring, and Winter begin and end there.*

1. IF the Place be in the Equator, we ſhewed in the preceding Propoſition when the Seaſons of the Year begin; each returning twice in one Year.

2. IF the Place be beyond the eighth Degree of Latitude, bring it to the braſs Meridian, and mark with Chalk the Place it is under; then turning the Globe obſerve what Part of the Ecliptic comes under the Mark, and when the Sun comes there, Summer begins; then obſerve the middle Degree between the Mark, and the Tropic of *Capricorn*, if the Place have a North Latitude, but the Tropic of *Cancer* if South; and turn the Globe 'till two Points of the Ecliptic come under that middle Degree: the one is the Place the Sun is in when Spring, the other when Autumn begins; and Winter will be when the Sun is in the firſt of *Capricorn*, if the Place be to the North, but *Cancer*, if to the South of the Equator. The ſame may be done by the Maps, but more accurately by the Tables of Declination.

IN which find the Declination equal to the Latitude, and againſt it you will have four Days of the Year; and take that Day for the beginning of Summer which is between the Tenth of *March* and *June*, if the Place be North; and between the Tenth of *September*, and Tenth of *December*, if South Latitude.

THEN take the half of the Latitude from eleven Degrees ninety five Minutes, and find the Remainder in the Table, you will ſee again four Days againſt it, in two of which the Sun is at a

mean Diſtance from the Place; and if the Place be North, take two Days, one between the Tenth of *December*, and Tenth of *March*, the other between the Tenth of *September*, and Tenth of *December*; the former will be the beginning of Spring, the latter of Autumn: but if the Place be in South Latitude, take the Day between the Tenth of *June*, and the Tenth of *September*, for the beginning of Spring; but for Autumn, take that between the Tenth of *March*, and Tenth of *June*; and Winter will begin the Tenth of *June*, or *December*, as the Place is South or North.

3. IF the Place have leſs than eight Degrees of Latitude, it will have two Summers, two Springs, and Autumn, and Winter, except we reckon the Spring between two Summers to be a Part of a long Summer, and then we do as in the former Caſe; but if we reckon there two Summers, and two Springs, according to our Definitions; find, as before, the beginning of Summer and Winter, and take out of the Table four Days at a mean Diſtance, and take two of them as before for the beginning of Spring, *viz.* that which is next to the firſt of Summer; and for the ſecond Summer's beginning, take the Day that is as far from the twenty firſt of *June*, as the firſt Summer's beginning.

PROPOSITION V.

In the Temperate *and* Frigid Zone *the four Seaſons are almoſt of the ſame Length; but in the* Torrid Zone *they are unequal; yea one and the ſame will be different in different Places there.*

THE

THE former Part of the Proposition is plain, because the Sun goes thro' three Signs in each Season, and so the Times will be nearly equal, excepting a few Days, *viz.* five that the Summer, and four that the Spring, in northerly Places, exceeds the Autumn, and Winter; and in Places southerly the Autumn and Winter exceeds the Summer and Spring as much, because of the Sun's Eccentricity; as we said before.

2. IN Places under the Equator there are two Summers (and likewise the other Seasons) and both short; and the two Springs also, each having only thirty Days, and both Summers and both Springs have sixty four Days, *i. e.* two Months, and two or four Days: but the Autumn and Winter have fifty five Days, and the two Autumns one hundred and ten, and the two Winters as many, *i. e.* near four Months.

3. THE nearer the Places in the *Torrid Zone* are to the Equator, they have the longer Summer, and the less Winter; and an Autumn and Spring more or less ordinary. In Places of less than ten Degrees Latitude, the Summer is no less than six Months; and how long each Season is, may be known by the preceding Proposition.

SO far of the celestial Seasons; but 'tis not from these only that Light, Heat, Cold, &c. do flow; there are other Causes, which we shall now consider.

PROPOSITION VI.

The Sun goes near the Zenith of Places in the Torrid Zone *at Mid-day; but at Mid-night goes far from it under the Horizon, and the Places are there almost in the middle of the Earth's Shadow, and the Sun's Rays neither enlighten nor warm their Air.*

In the Frigid Zone, *as the Sun is a great way from their Zenith even at Mid-day, ſo at Night it goes but a little way under the Horizon, and ſends ſeveral Rays by Reflexion into the Air there.*

In the Temperate Zone *the Sun is at Mid-day at an ordinary Diſtance from the Zenith, and at Night is a good Way under the Horizon in Winter; but ſends ſome Rays by Reflexion into the Air in the Summer-time.*

TO ſhow this by the Globe: elevate the Pole for the Latitude of a Place in the *Torrid Zone*, or rather put the Poles in the Horizon; and conſider the Parallels which the Sun deſcribes in revolving, how far they are above, and under the Horizon, and the firſt Part will be plain.

THEN elevate the Pole for the Latitude of a Place in the *Frigid Zone*, and you will ſee the Parallels are but a little way under the Horizon; which ſhows the ſecond Part.

AND again elevate for the Latitude of a Place in the *Temperate Zone*, and you will ſee the Truth of the Third Part.

PROPOSITION VII.

To find the Continuance of Twilight in a given Place, at a given Time.

IT'S Continuance is from the firſt appearance of Light to the Sun's riſing, and from Sun-ſetting to it's Diſappearance; which Aſtronomers have found by Obſervation to be at eighteen Degrees under the Horizon.

ELEVATE the Pole, to the Latitude of the Place, and find the Sun's Place that Day in the Ecliptic: which being marked, and the Mark brought to the Horizon, and the Index of the Hour Circle to twelve, turn the Globe 'till you find, by a Quadrant of Altitude, or a Pair of Compaſſes,

Compasses, that the Sun is eighteen Degrees under the Horizon; and you will see how many Hours the Index hath passed: and so long is the Light in disappearing in the Evening, and in appearing in the Morning; as may be tried in the East, supposing the Air to be clear, it will be convenient to give an Example in each Zone.

PROPOSITION VIII.

In Places in the Torrid Zone *the Twilight is least, and in the* Frigid Zone *greatest, and in Places in the* Temperate Zone, *in a Mean between the two.*

FOR under the Equator, and in Places near it, the Twilight, according to the somer Hypothesis, is about one Hour; but by Experience 'tis found to be but half an Hour, or a little more; because the Air, being so gross there, is not so high as is requisite to make Twilight at the Depression of eighteen Degrees; and besides, the Supposition of eighteen Degrees requires very small Light, such as in the beginning of Twilight: which by the Vulgar is not counted Twilight.

IN the *Frigid Zone* the Twilight lasts for several Days, while the Sun is under their Horizon.

IN the *Temperate Zone* the Twilight lasts three, four, five, or six Hours, and all Night in some Places in Summer-time, according as the Places are more or least near the *Frigid Zone*. These things may be all proved by the Method in the preceding Proposition.

PROPOSITION IX.

A Place being given in the Temperate *or* Frigid Zone, *and another Place in the* Torrid Zone, *and likewise*

likewise the Day of the Year, to find the Hour in the Torrid Zone *in which the Sun shall have the same Altitude (and so affect the Horizon with Rays of equal Force) as it hath in the* Temperate Zone *at Mid-day.*

ELEVATE the Globe for the Latitude of the Place in the *Temperate* or *Frigid Zone*, and bring the Sun's Place to the Meridian, and observe it's Altitude, and that is the Altitude of the Rays which warm and enlighten that Place.

THEN elevate the Pole for the Latitude of the Place in the *Torrid Zone*, and applying the Quadrant to the Zenith, mark on it the Altitude before found, and bring the Sun's Place to the Meridian, and the Index of the Hour Circle to twelve, and move the Globe and Quadrant 'till the Sun's Place agree with the marked Degree of Altitude, or the Quadrant, and the Index will show the Hour sought; and therefore the Rays falling in both Places with the same Obliquity, there is the same Degree of Light and Heat in both Places, except other Causes hinder it. *viz.* 1. That the Sun had before introduced a Temper into the Air of the *Torrid Zone*, which it had not into the the other Zones. 2. The Sun rising up more directly in the *Torrid Zone*, the Rays are all sent almost the same way; which will cause greater Heat than if it had ascended obliquely, and sent the Rays a great many Ways, which disperses them; whereas Heat requires they should be gathered together.

FOR Example; Let us find out in the equinoctial Day, and Hour, when the Sun is as high above the Equator as at *Amsterdam* at twelve o'Clock that Day.

PROPO-

PROPOSITION X.

To explain the Causes of Light, Heat, and the Seasons, shewed in the preceding Proposition, under the Torrid Zone.

1. THE Sun rises up directly above the Horizon every day, especially under the Equator, to the Meridian and Zenith of the Place, and therefore the Rays decline from the Perpendicular at nine in the Forenoon about forty Degrees, and come still nearer to a Perpendicular as they approach to the Meridian, and afterwards decline from it 'till four in the Afternoon, when the Sun begins to send the Rays very obliquely; and therefore the greatest Heat is between nine and three or four o'Clock, if no other Cause hinder; and because the Sun in their Meridian hath different Distances from the Zenith, it is Winter when most distant, and Spring at a mean Distance going from the greatest Distance to the Zenith, Autumn while it goes from the mean Distance to the greatest, either at the first of *Cancer* or *Capricorn*.

2. IN Places under the Equator the Sun is never less than twelve Hours above, and as many below the Horizon; but in other Places of the *Torrid Zone* 'tis an Hour, or at most an Hour and thirty Minutes more above in the Summer near *Cancer* or *Capricorn*; and as much in the Winter less than twelve Hours: which causes the Nights to be a little colder, and the Heat of the Day of less continuance in the Winter-time.

3. IN the Night the Sun is far under the Horizon, so that there are scarcely any reflected Rays to enlighten the Air; which causes the Cold to increase; and the Air being condensed thereby, to

fall dow by it's Weight; and their Twilight there is only for about half an Hour.

4. THE ſame way the Moon riſes almoſt perpendicularly to the Horizon, tho' a little more obliquely, becauſe it goes five Degrees from the Ecliptic, and continues a little above twelve Hours above the Horizon, and almoſt as many below, going far under the Horizon. And thus it may, by it's perpendicular Rays increaſe the Heat of the Night, eſpecially if near the Zenith; but the effect is ſcarce ſenſible by it's ſhort continuance above the Horizon.

5. ALL the Stars riſe and ſet in Places near the Equator, but in Places near the Pole they do not; and may therefore cauſe ſome ſmall Light, and Heat in the Air,

6. IN ſeveral Places of the *Torrid Zone*, as in the *Indian* Iſlands, and *India* itſelf, and in the South Part of *Africa*, and in *Guinea* in *Africa*, and *Mexico* in *New Spain*, the Earth is ſulphureous, and ſends forth more hot Exhalations, which give Heat, and ſome peculiar Properties to the Air. In ſome Places 'tis ſandy, as in the North Part of *Africa*, and in a Part of *Libya*, the *Blacks* Country, and in ſeveral Places in *Arabia*, in *Peru*, and Places between *Peru* and *Braſil*; in which Places there is great Heat from the Sand that retains the Heat from the Sun long, and communicates it continually to the Air; in other Places there are ſeveral Rivers, but few in theſe; and in *Abaſſia*, *Guinea*, *Congo*, *India*, and *Braſil*, there are many Rivers that afford moiſt Vapours, which beat back the Sun's Heat ſo as to make it more tolerable.

7. SEVERAL Places in the *Torrid Zone* have the Sea near them, as in *India*, and the *Indian* Iſles, and the South Part of *Africa*, *Guinea*, *Braſil*, *Peru*, and the *Mexican Spain*; few Places of the *Torrid Zone* are inland Parts, as the middle of *Africa*, and the

the Countries between *Peru* and *Brasil*, where the Heat and Drought is greater than the former, where the Air is more moist, cxcept other Causes concur to hinder.

8. MOST Countries in the *Torrid Zone* have the Sea almost round them, and in their middle a Chain of Mountains more or less high; as *India*, and the *Indian* Isles, the Tongue-like Part of *Africa*, *Peru:* and this alters the Light, Heat, or causes Rain there; in some Places they keep off the eastern Sun, and in others the western. And the Rains caused there, (as in *Chap.* 20.) hinder the Light and Heat; and there are but few Places there without those Things, as the Heart of *Africa* and *Mexican Spain*, or may be more.

9. THE Effects of the Winds in the *Torrid Zone* are various and remarkable; for the general Winds blowing to the West cool the Places in the eastern Shores of *Africa* and *Brasil*; but not those on the western, as *Peru*, *Guinea*, *Congo*, *Angola*. Some Winds are peculiar to some Places; as the South Winds in *Peru*, which carry the Vapours before them; other Winds are stated, (as in *Chap.* 21.) which change the celestial Seasons, blowing as contrary as the Heavens move.

THE Clouds and anniversary Rains in several Places of the *Torrid Zone* alter the Influence of the Sun; being as constant almost as the Sun's Motion: and they are mistaken who think all things in the sublunary World are inconstant, and without Order; and that only the heavenly Bodies are constant in their Motions.

AND seeing those causes are so many and various, some prevailing in one Place, some in another; some at one time, and some at another; either concurring with, or opposing one another, no wonder the Seasons in the *Torrid Zone* should be so changeable.

PRO-

PROPOSITION XI.

To determine when, or in what Months of the Year, the four Seasons happen on the Earth, viz. *Spring, Summer, Autumn, and Winter, in different Places in the* Torrid Zone.

WE ſhewed, *Prop.* 2. that the Seaſons in ſeveral Places of the *Torrid Zone* do not agree with the Sun's Motion, for 'tis Winter there when the Sun is at, or near, their Zenith; and Summer when it is fartheſt off: for which reaſon we diſtinguiſh between Seaſons that are Celeſtial, and thoſe that are Terreſtrial. We ſhewed alſo in *Prop.* 3. and 4. when they had the celeſtial Seaſons in the *Torrid Zone*: and ſeeing the terreſtrial happen not at the ſame Times, or conſtantly at one Time, in different Places, we muſt determine their Times from Experience, and as much as can be ſhown why they do not agree with the other Seaſons in the Heavens; and that from theſe ten Cauſes in the firſt Propoſition. And firſt, we muſt know that 'tis not a raging Cold, or Froſt, that makes Winter in the *Torrid Zone*, but Rains, or leſs Heat than in Summer; and likewiſe in ſeveral Places of the *Torrid Zone* there are only two Seaſons of the Year, Summer and Winter, which are chiefly diſtinguiſhed by wet and dry; for in Winter there is ſometimes more Heat than in Summer, with a difficulty of breathing, for the Clouds and Rain beat down the warm Air; and Spring and Autumn are not ſo obſerved and diſtinguiſhed by Signs.

LET us begin with that Part of *Africa* which is in the *Torrid Zone*, and go round eaſtward to *Braſil* thro' the whole *Torrid Zone*.

THE Countries on the weſtern ſhore of *Africa*, from the Tropic of *Cancer* to *Cape Verd*, which is fourteen Degrees North Latitude, are all fer-

tile in Corn, and several sorts of Apples, and abound in Cattle, and the Inhabitants of robust Bodies; the Heat there being a little above what is in a Medium; so that they go naked, except their Nobility and rich Men, who cover themselves with Cloaths. The Cause of the Fertility and temperate Air there, tho' it be in the *Torrid Zone*, is, 1. The many Rivers, the chief whereof are *Senega* and *Gambea*, that water the Country, and render the Air the colder. 2. The neighbouring Sea; which affords moist Vapours, and cooling Winds; but how the Seasons are here, and in what Months their Summer and Winter, I have not found among Writers, thro' their Folly or Negligence; tho' I found in a Journal, that in one of the Isles not far from *Cape Verd* called *Hesperides*, or *St Vincent*, in Latitude sixteen, the rainy Months, *i. e.* their Winter, are *August*, *September*, *October*, *November*, *December*, and *January*, which Time agrees almost with the Season by the Sun's Motion; for in *May*, *June*, and *July*, because the Sun is at, or near, their Zenith, it makes their Summer Season, when they have the Air more hot and dry, without Rains; and in *February*, *March*, and *April*, it is Spring: for the Sun is then moving from the mean Distance to their Zenith, and they have Heat in a Medium without Rain; and *August*, *September*, and *October*, make Autumn, because of the Rains then, tho' it should begin sooner, for the Sun is not in *August* come back to a mean Distance; and *November*, *December*, *January*, are Winter, the Sun being then furthest from their Zenith; and then they have much Rain, and some Cold; but the Writer says 'tis not so every Year, but for the most part; and does not remember how the Seasons are in the neighbouring Continent of *Africa*; only he adds 'tis quite otherwise on the Shore of *Sierra Leona*, as we shall now show.

2. THEN

2. THEN the South Part of *Africa* that runs East and West, called *Guinea*, that is four or more Degrees of Latitude North. There is continual Heat, without intervening Cold; yet there are ſome Months they call Summer, others Winter; for on the Shore of *Sierra Leona*, and at ninety Degrees of North Latitude; and in ſeveral Places of *Guinea*, they eſteem that *March*, *April*, *May*, *June* and *July*, make their Winter, eſpecially *April*, *May*, and *June*; for there falls then ſo much Rain that is hot or warm, and there are ſuch Thunder and Lightning frequently, and ſuch Storms and Hurricanes as cannot be conceived by any but thoſe that have ſeen them. The *Portugueſe* call thoſe Storms *Travados*, which we mentioned in *Chap.* 21. And in theſe Months the Fields lie waſte, without growing Corn; but after the Storms are over, they dig the Ground that is dry, the Rain being drank in, and mix broken Pieces of Coal with it inſtead of Dung, and let it rot in the Earth for ten Days, then they throw in the Seed; for there is ſo much Heat in the Air, joined with a Moiſture from the adjacent Sea, that if Fiſh be kept half a Day unboiled after they are taken they ſtink. In theſe Places then, their Winter is in *April*, *May* and *June*, when the Rains abound, and the Storms rage; and the Spring in *July*, *Auguſt* and *September*; and Summer in *October*, *November* and *December*; and Autumn in *January*, *February* and *March*, when the Rains and Storms begin.

BUT theſe Seaſons are no way agreeable to the Sun's Motion; for there ſhould be a violent Summer there in *May*, *June* and *July*; for the Sun is then at, or near, their Zenith at Mid-day, which the Heat of the Air and Rains teſtify; and in *October*, *November* and *December*, there ſhould be Winter, for the Sun is then furtheſt from them. 'Tis not eaſy to account for thoſe Storms and Lightning they have when the Sun

Sun is so near their Zenith; it seems to me that the Sun draws up a great Quantity of Vapours from the Sea, and sulphureous Exhalations from the Land of *Guinea*; for 'tis a metalline and sulphureous Earth there, which being condensed by the cold night Air makes Rain; there being no constant Wind blowing to dissipate the Vapours, but a Calmness for the most part before the Storms come; and when these Rains fall the Air is hot, or warm; the Sun being vertical, and the Heat is suffocating; which makes a Difficulty in their breathing.

AND tho' their Fields lie waste in the wet Months, yet their Trees and Bushes bear Fruit all the Year round.

THE Day is here almost equal to Night thro' the whole Year; the Sun rising at six and setting at six: but the Sun is seldom seen rising or setting there, for it rises for the most part covered with Clouds for half an Hour; and sets after it hath been involved in the Clouds half an Hour.

TIS also worth remarking, why in the Months of *July* and *August* the same Rains and Storms prevail not when the Sun is then as near them as in *May* and *June*; and why in the Isles of the *Hesperides*, which are not far from *Sierra Leona* and *Guinea*, the Winter happens in other Months; but here the Summer is from the Sun's Course.

4. HOW the Seasons are in the inland Parts of *Africa* included between an Arch of the Tropic of *Cancer*, and the western Shore of *Africa* and *Guinea*, called the *Blacks* Country, I have not found any thing said of it; but that all things there are almost barren, except those Places near the *Niger*, which overflows each Year in *June*, *July* and *August*, and makes the Land there very fruitful, and forms several Lakes. The other Places on the Confines of *Libya* are oppressed with Heat, being sandy for the most

moſt part; and the rainy Months do not ſeem to be here as in *Guinea*.

4. THERE follow the Countries in the Tongue-like Part of *Africa* (which runs North and South) as *Maniconogo*, *Angola*, *&c.* from the ſecond Degree of North Latitude to the Tropic of *Capricorn*; for the Kingdom of *Congo* begins at the ſecond Degree of South Latitude. Their Winter there is like the Spring at *Rome* and *Italy*, being a temperate Heat; they never change their Cloaths, and the very Tops of the Mountains are warm there; the rainy Winter begins almoſt with our Spring, *viz.* the twenty fifth of *March*, and laſts during *April*, *May*, *June*, *July*, and *Auguſt*, to the fifteenth of *September*; and then the Summer begins, which continues 'till the fifteenth of *March*, in which there are ſcarce any Rains, but a conſtant Clearneſs: yet in Winter the Sun is ſcarce ſeen in any one Day for the Rain and Clouds. It rains not during the whole Day, but for the moſt part two Hours before Mid-day and two Hours after: great Drops fall which are immediately drunk up by the thirſty Grounds. Tho' the Inhabitants make but two Seaſons, Summer and Winter, as ſome do here; yet they may be reckoned four; Summer from the fifteenth of *December* to the fifteenth of *March*; and Spring from the fifteenth of *September* to the fifteenth of *December*; and Autumn from the fifteenth of *June* to the fifteenth of *September*; and the reſt Winter, *i. e.* from the fifteenth of *March* to the fifteenth of *June*.

THE Seaſons that are Terreſtrial agree nearly with the Sun's Courſe; for the Sun goes from them, from the fifteenth of *March* to the fifteenth of *September*, and is furtheſt the fifteenth of *June*; and in the reſt of the time it comes to them, and is vertical the thirtieth of *September*; and then goes to a mean Diſtance ſouthward, and returns from it in *October*, *November*, *December*, *January*, and *February*,

ary, and is vertical again the fifteenth of *March*; and in these Months they have Summer by the Sun's nearness; there being no Cause on the Earth to hinder it; and then 'tis Winter from the fifteenth of *March* to the fifteenth of *September*, for then the Sun hath removed from them; but the four Seasons we suppose them to have, do not so well agree with the Sun's Course; and I doubt whether they reckon the Spring and Autumn.

BUT the Cause we gave of the rainy Months, *viz.* that the Sun is then going from them, seems sufficient to produce that effect of itself, therefore we add another; that is, the Chain of Mountains that are to the East from the Sea-Coast; they are still covered with Clouds, occasioned by a stated North-West Wind that blows there at that Time. The Sun draws up the Vapours from the Sea, which that Wind carries against the Mountains; and the general South-East Wind makes also some Resistance to it, and they are thus condensed into Rain; and thence come the constant Rains and Showers, which cause also the overflowing of the *Nile*, and other Rivers in *Africa*; of the natural Cause of which, take the following account.

" THE River *Nile*, according to best Geogra-
" phers rises about fourteen or fifteen Degree of
" North Latitude, which is between the Tropics,
" about nine Degrees to the southward of the Tro-
" pic of *Cancer*, and in it's Course to the north-
" ward towards the *Mediterranean*, it runs into a-
" bout thirty Degrees of North Latitude before it
" falls into the *Levant*, and as it is so large a River
" and runs thro' the low Grounds of *Egypt*, it can-
" not avoid being the Receptacle of a great Conflu-
" ence of Rivers, by whom all those heavy Rains
" that fall in or near it's Passage, or upon the adja-
" cent Mountains, are convey'd into it's Chanel, and
" having no way to disgorge itself till it falls into
" the

" the *Mediterranean*, it is no more difficult to ac-
" count for its overflowing the low Land of *Egypt*
" in its Paſſage thro' it (tho' a thing look'd upon
" by the Antients as ſupernatural) than it is to ac-
" count for a Land-flood after a ſudden heavy Rain
" in *England*, or elſewhere. This Conſideration
" makes the overflowing of the *Nile* ſo far from be-
" ing a wonder, that it would be a much greater
" wonder and more difficult to be accounted for, if
" all theſe exceſſive and durable Rains that fall in-
" to the River *Nile*, and that from the adjacent
" Country deſcend into it between or near the Tro-
" pics where theſe Rains fall; I ſay it would be a
" much greater wonder how theſe heavy Rains and
" prodigious Quantites of Water could be convey'd
" to the Sea, and the *Nile* not being affected there-
" with; and altho' the *Nile* ſeems to be more taken
" notice of generally than any other River in the
" World for its annual overflowing, as if it was a
" Property peculiar to itſelf only, yet we find *Ton-*
" *quin*, *Siam*, and other Places within or near the
" Tropic, that not only have theſe ſtated annual
" Rains and Overflowings, but depend ſo much up-
" on them, that they have not Moiſture ſufficient to
" prepare the Ground for their Rice without them,
" and if the Rains fail, they have ſcarce any Crop,
" and the Poor are miſerable for want of Suſtenance,
" as is the Caſe upon the *Malabar* and *Cormandel*
" Coaſts, as well as at *Tonquin*, the Floods being
" there generally as certain and conſtant as in the
" *Nile*, or any other Place under or within the
" Tropic, and proceeding from the ſame Cauſe."

MOREOVER, the Rivers in *Congo* overflow in theſe rainy Months, and make great Fruitfulneſs there, as much, ſome ſay, in *Egypt*; and all things grow and ripen excellently.

5. IN the Province of *Lowango*, that borders on the Sea, not far from *Congo*, in Latitude four Degrees, there are alſo wet Winter Months, and clear

clear Summer Months; but what is strange, the Months are not the same in which the Rains come in the next Kingdom; for there are continual and vehement Rains in *Lowango* from the first of *January* to the first of *May*, when yet 'tis Summer in *Congo* in *January* and *February*, and the Sky clear, which is contrary to the celestial Season, for the Sun is not furthest from them in *January* and *February*, and so they should have no Rain, but dry Weather, which must come from some other Mountains, or stated Winds, *&c.*

6. THE Isles of *St Thomas*, in the Equator, and *Annobon*, in Latitude one Degree thirty Minutes, are most fertile in Sugar, Corn, Apples; but especially Citrons, and Oranges.

7. HOW the Seasons are on the western Coast of *Africa* from *Lawango* southward I find not.

8. THEREFORE we come round the Cape to the eastern Shore of the Tongue-like Part of *Africa*, where there is *Zofala*, *Mosambique*, *Quiloa*, to the Equator: the Winter there is from the first of *September* to the first of *February*, and Summer the rest of the Year; whereas in *Congo* the Winter we said was at another Time, tho' both Places have nearly the same Latitude; but this is owing to the Chain of Mountains that divide that Part of *Africa* into East and West Land.

THE Land in the East Part is not so fertile, but barren and sandy in many Places, and is burnt with Heat sometimes; tho' the Sea, Rivers, and general Winds, temper the Heat.

9. THE other Countries all the way to the Mouth of the *Arabian* Gulf, and from thence along the Shores of the Gulf to the Tropic of *Cancer*, what Seasons they have we cannot learn; only that 'tis all barren and sandy, and so must be very hot: (the Sterility and Heat among the *Troglodytes*, or *Snake-Eaters*, in *Arabia* is famous); and

besides this there are almost no Rivers to water the Country; but we shall wait for better Accounts.

10. BUT what must the Seasons be among the *Abassines* in the inland Part of *Africa*, where the Equator cuts it almost in the middle?

11. BUT leaving *Africa* we go to the Countries in *Asia* in the *Torrid Zone*; where we meet with *Arabia* on the *Red-Sea* from *Mecca* to *Aden*, twelve Degrees North Latitude, having the Mountains of *Arabia* on the East. They have great Heats there in *March* and *April*, and more after that when the Sun goes thro' their Zenith, and keeps near it in *May*, *June*, *July*, and *August*; the Heat being so great, that they are forced (at least the richer sort) to cause Water to be continually thrown on them in the Day-time, or else they lie in Cisterns filled with Water: the Merchants at *Aden* meet together at Night for Business, and even then they are hot enough. I suppose 'tis for want of watry Vapours from the Earth; which is stony, and hath few and small Rivers in it. And as for the Vapours from the *Red-Sea*, the general Wind, tho' weak there, yet carries them westward; there is also a great deal of Sand, which retains the Heat it received in the Day all the Night long; and communicates it to the Air.

AND this Time of their Winter and Summer agrees with the Sun.

12. THERE is the same Account to be given of all *Arabia*, and it's eastern Shore.

13. IN *Cambaya* and *India*, which is under the Tropic of *Cancer*, and on the *Malabar* Shore in the *East-Indies* towards the West, which reaches to the eighth Degree of North Latitude, the wet Season is from the Tenth of *June*, to the Tenth of *October*; but chiefly from the middle of *June* to the middle of *September*: nor doth it rain

rain the same time in all these Places, but more constantly in the Province of *Goa* and *Cochin*, and less in *Cambaya*, where it rains but three Months and seldom at other times: but in *Goa* the Rains, tho' not so vehement, begin in *April* and *May*, with Thunder and Storms; so that we may count Autumn here from the fourth of *March* to the fourth of *June*, and Winter from that to the fourth of *September*, and Spring from that to the fourth of *December*, and Summer from that to the fourth of *March*: for there is a great Drought then, the Water of the former Rain being now drawn out of the Earth. But the Inhabitants count only two Seasons, Summer and Winter, or rather wet and dry, there being no Winter there, according to our Notion of it; yet 'tis as properly called Winter from the Rains as from Cold.

BESIDES these Rains on the Shore, there are Storms and Thunder in the wet Months, and the Sea is then said to be shut up, and the Rivers then overflow. In the Month of *September* the Sea begins to be open, and the Ships begin to sail from the *Malabar* Shore to all Parts of the World: nor is the Rain severe in the Fields, for they have time to plant and sow for many Hours of the Day (except when there are Storms). For they sow during these rainy Months, which they do not in *Guinea*, as we said; and the Air is then of a moderate Heat by reason of the Clouds covering the Sun; so that they take their Diversions in the Fields from the Shore, where there is no Inundation. The Fertility from the Rains is almost incredible; and if there happen to be no Rains, as in 1630, all their Hope of a Crop is gone; and there comes a Dearth of Provision, a hot unwholesome Air, Fevers, Pestilence, and Myriads of Men die. In the Year 1630 Man's Flesh was publickly sold in the Stalls of some Towns in *Cambaya*. The Rains are sometimes

ſo vehement that their Houſes, ſlightly built, fall down, and the Rivers carry others away.

THEY ſow in *May* and the beginning of *June*, and reap in *November* and *December*; but 'tis otherwiſe in *Guinea*.

THEIR Summer and Winter are not according to the Sun's Motion, for in *July* and *Auguſt* the Sun is vertical, or nearly ſo, and thus they ſhould have Dryneſs and Heat. In this they are very happy, for if the Rains did not fall, and the Clouds continue to cover the Sun, the great Heat of the Sun would make the Land ſandy and barren, like *Arabia* and *Libya*, where they have not theſe Rains when the Sun is vertical; and in *December*, *January* and *February*, they ſhould have Winter, or Rains and leſs Heat, the Sun being then at the greateſt Diſtance: but they have Summer then; yet the Air is cold enough at Night, and from twelve at Day to twelve at Night there blows a refreſhing Gale from the Sea.

14. IN the oriental Shore of *India*, called *Cormandel*, the Seaſons differ from the Heavens; for the Sun there cauſes great Heat in *March*, *April*, *May*, and *June*, and no Rains. The *Saracens* divide the Year into three Seaſons, hot, wet, and cold. The Heat from the fourth of *May*, to the fourth of *June* is intolerable, the Wind blows from the North, to which if you turn your Face you will feel ſuch Heat in the Air as is perceived near a red hot Furnace; for the Sun is then to the North at Mid-day; and the Stones and Wood are very hot, but the Water in the Wells very cold, ſo that many are killed by drinking it when they are hot.

THE greateſt Heat is between nine in the Forenoon 'till three in the Afternoon, and then there is no travelling; but at other Times 'tis temperate and tolerable, and the Air clear and pleaſant, and travelling delightful.

THE

THE wet Season is from the first of *July* to the first of *November*; and the Cold from the first of *November* to the first of *March*; and in *January* and *December* the Cold in the Night is sensible enough.

THERE are here several Things that deserve to be enquired into; for from the first of *March* to the first of *July* the Sun is nearly vertical to them, and no wonder if the Heat be great then; yet one would think it should be as hot in *July* and *August*, when the Sun is also over them, and hath the Advantage of the former Heat, and so should be greater: and besides, how come the Seasons there to differ from those on the *Malabar* Shore, being both in the same Climate, and having the Sun vertical and remote at the same times? And which is more strange, there is only about seventy Miles, and in some Places only twenty Miles Distance between them; so that you may come from the Places where the Air is clear and hot, to where 'tis rainy, in one Day. *Maffæus* writes thus: 'There 'are, says he, other things very strange in that 'Country; but what especially puzzles Naturalists 'is, that in the same Months there should be Sum'mer beyond the Mountains of the *Gate*, which 'run all the way to the Promontory of *Cours*, and 'on this Side the *Gate* there should be Winter, 'and constant Rains; the People, tho' near one 'another having opposite Seasons.' So far *Maffæus*.

AND this is observed also in other Places, as we have and shall show. It arises from the Situation of the Mountains which divides *Cormandel* and *Malabar*, running North and South, together with the stated Winds; for on the Shore of *Cormandel* the general Wind is more felt, except in the Summer Months of *May* and *June*, which drives the Vapours against the Mountains, which makes Rain in *Malabar*; the Mountains are still observed cover-

ed with Clouds in the wet Months, and the Showers more vehement on them when it rains in *Malabar*: but when it rains in *Cormandel* the Sky is clear on the Mountains, as in *Malabar* itſelf; excepting the Months of *July* and *Auguſt*, for then it rains in both.

15. IN the Countries on the Coaſt of the Sea at the Mouth of the *Ganges*, which are oppoſite to the Shores of *Cormandel*, and are alſo in the North *Torrid Zone*; as *Siam*, *Begu*, the Peninſula of *Malacca*, the rainy Months, which cauſe the Rivers to overflow, are *September*, *October*, and *November*; but in the Land of *Malacca* it rains every Week of the Year twice or thrice, except in the Months of *January*, *February*, and *March*, in which there is a continual Drought; this is all againſt the Sun's Courſe, whence the Cauſe muſt be from the Mountains, or ſtated Winds, or the adjacent Sea. But becauſe we have not Obſervations of theſe Countries accurate enough, we will not inſiſt on them. The overflowing of the Rivers is the chief Cauſe of the Fertility: and the adjacent Sea, the ſtated Winds, and the Rivers, temper the Heat there, which makes it pleaſant living; there being a plentiful Crop of all kinds of Fruits. In the Kingdom of *Patana*, and near it, the Summer begins with *February*, and laſts to the end of *October*; in which Time there is a conſtant Heat, which is moderated with a conſtant Eaſt Wind, and the Air very wholſome. In *November*, *December*, and *January*, there are conſtant Rains, which yet hinder not a new Crop of Fruits every Month; and the ſame may be ſaid of *Cambaya*; and this Winter agrees with the Sun's Courſe.

1. LEAVING *Aſia*, and ſailing thro' the *Pacific* Sea, we come to *America*, which is under the *Torrid Zone*, and it is either North or South; and the South is either at *Peru* or *Braſil*, which, tho' near,

near, yet have their Seasons at different Times. The Country of *Peru* may be divided into that Part on the Sea, that where the Mountains are, and the Plain beyond the Mountains, which are all in the same Climate. In the mountainous Places they have their rainy Winter from *October* to the end of *March*, when one would think they should have Heat from the Sun's Nearness; and have Summer from *April* to *October*, in which Time they have no Rain, which they have constantly in Winter; and so the celestial and terrestrial Seasons differ.

IN that Part of *Peru* next the Sea they have almost no Winter the whole Year, having no Rain; but they count it Winter from *April* to *October* (which agrees with the Heavens, for then the Sun is gone from them to the Tropic of *Cancer*, and is returning again): for tho' it doth not rain then, yet the Air is cloudy, and the Sun hid, and it looks as if it were just going to rain, when yet none falls, except a Dew, especially in *June*, *July*, and *August*, every Day before Mid-day: and the dark Weather is not unwholsome, but the Cloud turning to dew it falls down and waters the Vallies. It doth not then rain on the mountainous Places, but the Air is clear. Thus Part of *Peru* on the Shore, is distinguished into Vallies and sandy Places; the Vallies are most fruitful, and the sandy Places between the Vallies are barren: and in the adjacent Islands likewise it never rains; only there falls a great Dew.

YET in the Island of *Gorgon*, which is in three Degrees of South Latitude, it rains for eight Months, with such Thunder and Storms that one would think Heaven and Earth were blended together; but in *May*, *June*, *July*, and *August*, there is Summer, and a Drought; against the celestial Season.

IN ſome Parts here under the *Torrid Zone* there is a conſiderable Cold; for in the Province of *Paſtoa*, in the Country of *Popay*, in the Valley of *Artiſina*, the Seaſons both of Summer and Winter are ſo cold that the Corn does not grow. In the Fields about the Town of *Caſco*, near the middle between the Equator and Tropic of *Capricorn* there is no ſmall Froſt; and Snow is found there ſometimes.

FROM hence we underſtand that *Peru* is not very hot, but enjoys rather a moderate Air all the Year, excepting the ſandy Ground and hilly Places. The Vallies appear fruitful and pleaſant, with their product of Trees and Corn. They have their Water from the Dew that falls, as I ſaid, every Day; and in Summer from the Torrents that flow down from the mountainous Places; for there is Winter by the conſtant Rains: and from theſe Torrents they let in the Water to their Vallies; tho' ſome Vallies are ſatiated with the Dew itſelf, and are very fertile.

THE Cauſe of this Difference between the Seaſons on the Plains and the Mountains of *Peru*, and why it never rains in the Plains, is not ſo obvious: for they are ſo near one another, that one may go from the Rain in the Morning to the Plain where there is a clear dry Air. It ſeems to come, 1. From the Chain of Mountains. 2. From the South-Weſt Wind peculiar to that Place, and which is conſtantly there. The Wind drives the Vapours againſt the high Places whereby they are condenſed, or elſe it diſſipates them ſo that they are not condenſed on the Plains. We ſhewed in the Chapter on Mountains how they come to theſe high Places.

PERU hath this in common with *Egypt*, and ſome other Places, that the South Winds are not wet and warm, but rather clear up the Air; which ſeems

ſeems to be in all thoſe Places in South Latitude.

17. THE South Part of *America* call'd *Braſil*, on the Eaſt Side between two Degrees of South Latitude to twenty four Degrees, hath ſo pleaſant and wholſome an Air, that no Place excels it, as *Piſo* on the Seaſons there, in his Book of the *Medicine in Braſil* tells us: it's forepart that is inhabited hath always a pleaſant and favourable Gale from the Eaſt, which ſeems to be the general Wind and not any ſtated Eaſt Wind, that refreſhes Man and Beaſt, keeping them from the intolerable Heat of the Sun that is juſt above them: and if the Sea flow with it, it comes early in the Morning, but if the Sea flow back from the Shore, 'tis plainly perceived to be later: nor doth it grow weak in the Evening, as in ſeveral Places of *India*, but is ſtrengthned with the Sun that moves with it weſtward, and continues briſk till after Midnight. Nor can the nocturnal Condenſations overcome the Dilation and natural Motion of the Air that Way.

ON the Weſt Side of *Braſil*, which ſeparates the vaſt tract of Mountains from *Peru*, there is a Weſt Wind, which tho' it be unwholſome and late at Night moleſts them by coming over a vaſt many unwholſome Bogs, yet it is reſtrained by the Mountains, and beat back by the morning Gales, that it ſcarce reaches the eaſtern Shores.

THOSE pleaſant Seaſons, tho' they continue without much Alteration, yet there is a Difference in the Night and Day of them; which differ as much, as to heat and cold, as they are equal in length: for when the Sun comes near their Zenith, and hath opened the Pores of the Earth and of their Bodies, it goes far under the Horizon; whence ariſes a greater Condenſation and Coldneſs in the Air in the latter Part of the Night, when the Dew falls more plentifully; and this rigid Cold continues from three in the Morning, about Cock-crowing,

to

to the Sun-rising; and affects their Bodies so as to be hurtful to Strangers; and if they guard not against it, they will have no pleasant Life, either there or on the other Coasts of *India*; which they in *Brasil* know well; and therefore have good Fires constantly at their Beds in the Night, against the cold, and venemous Insects.

MOREOVER, the Sun's rising and falling straight up and down makes a short Twilight; and the Days and Nights to be so equal, as not to be one Hour different.

IN the Summer Nights the Cold is more intense than in the Winter Nights; which is strange: and it is plainly perceived to be more mild in Winter, when the Air is calm and pressed on all Hands by Clouds, while 'tis gathering the Vapours into Rain.

THE beginning of the wet Season is in *March* or *April*, and is over in *August*; for the Sun returning from *Cancer* doth turn the Vapours into Wind; whence arise Storms and Whirlwinds, which the Spring doth soon settle. Those about the Tropics find no change as to the Seasons while the Sun comes to them, and goes from them twice in the Year, as some have thought; (tho' we have given Examples to the contrary, and even here in *Brasil*) but only when the Sun goes from the Equator either South or North.

THERE are only two Times of the Year, one hot and dry, called Summer, the other hot and wet like the *European* Summer, which is their Winter, which is observed in all the *Indies* between the Tropics. The beginning and end of Summer and Winter doth not happen at the same time, because of some Things peculiar to each Place, and the different Distance from the Equator; yet the Year may be said to contain six Months inclining to a wet, and the other six to a dry Air. And tho' in several Coasts of *Africa* and *Asia*, of the

same

ſame Latitude with us, there ariſe from thence different degrees of Heat, there is little or none, tho' the Sun goes juſt over their Zenith in *Braſil* in *October* and *February*, and ſtrikes the Earth with Rays almoſt perpendicular.

THIS diverſity of Heat threatens Death to the Inhabitants by the frequent noxious hot Calms; but here it promiſeth conſtant Health by an over-ruling Gale.

WHENCE we may learn that the Seaſons are not ſo much from the Sun's Motion as from the kinds of Wind, and the different Aſpects of the Stars, or Situation of the Place.

SO that in the inland Parts of *Braſil* towards the Weſt, the Nights have been ſo much colder than nearer the Sea, that the Hair of the Head hath been covered with Hoar-froſt in the Morning.

AND there is alſo in the weſt of *Braſil* a Summer and Drought, at the ſame time that there is in the Eaſt, Winter Rains, and dark Weather.

YOU may indeed often ſee the Heavens covered with Clouds brought from the Eaſt to the Weſt, but they are thin and much rarified, when the wet Days are not. The Sun when riſing or ſetting may be looked on with ſteddy eyes; there is a wonderful clear Sky every where, eſpecially in the evening, and the Moon that ſucceeds in the Night finds no Vapours or Clouds in the Air; it being ſo clear that the old and new Moon may be ſeen in one and the ſame Day; and Letters may be read when 'tis but quarter Moon.

THE different Aſpect of the Planets, with other concurring Cauſes, gives a bad Temperature to the Air, which in the Evening flaſhes frequently with Lightning, even in the cleareſt and drieſt Seaſons.

THE

THE Drops of Rain are very large, and fall down with great Force; and there is a suffocating Heat that follows, or goes before them.

THE Dew here, especially in Summer, is fatter than that in *Europe*, and more fertile, being more impregnated with Nitre, and more penetrating; being more refined, as appears in it's corroding all Metals, especially Iron; not to mention other Things that are less solid,

THE Meadows and open Fields, tho' less than in Summer, yet mostly in rainy Months, are delightfully green, however discommoding to the Inhabitants; and tho' they can have no Harvest then, there is Food for their Cattle. So far from *Piso*. And to make the better Judgment we shall mention somewhat from other Authors. All the Fields in *Brasil* rise into little pleasant Hills; there being no high Mountains on the Shores, tho' at some Distance there are seen a few here and there among the dry Hills; and not in every Place, but at the interval of some Miles there are Vallies, watered with little Rivers, which make them fruitful, not in the rainy Months only, but even in Summer. The Hills themselves are by the Heat of the Sun dried up, that not only Grass, but the very Trees sometimes die. It seldom rains all Day, and all Night too; and very seldom for one Day without intermission. The rainy Months are not always the same. In the Year 1643, as *Marcgrave* observed, it rained seven Months, from the first of *February* to the first of *September*, but especially in *May* and *July*; and in 1640 it rained the same time, but especially in *April*, *May*, and *July*; and in 1642 there were six rainy Months, *March*, *April*, *May*, *June*, *July*, and *August*; and it is much alike in other Years. Yet these Observations are only concerning one Place in *Brasil*, *viz.* *Pernambuca*, in eight Degrees Latitude; but those

those are not the rainy Months in all Places; nor does the Rain begin and end at the same time in every Place,

IT hence appears, that the Summer and Winter in *Brasil*, somewhat agree with the celestial Seasons; the Rains begin at the Sun's greatest Distance; and in the mean and least Distance southward there is Heat: tho' there are in some Places some Things that do not so well agree, because of the Winds and Situation of the Places.

18. SO much for South *America*. But North *America* is quite otherwise; for in *Nicaragua*, a large Province, whose middle is ten Degrees North Latitude, it rains six Months, from the first of *May* to the first of *November*; in the other Months 'tis hot and dry in the Night as well as the Day, which is against the Sun's Course; for in *May*, *June*, &c. the Sun is at, or near, the Zenith, and then they should have Heat and Drought, and not Rains; and in *November* and *December* 'tis more remote, and then there ought to be great Rains.

THE Mountains at *St Martha*, in eleven Degrees North Latitude, are for the most part covered with Snow.

THUS we have considered the Seasons in the *Torrid Zone*; from which we infer,

1. THAT there is scarcely any Cold to be felt in some Places; their Winter consisting in rainy Weather. 2. In some Places the Cold is sensible enough. 3. In the Night especially, 'tis cold in the last Watch; the Sun going so far under the Horizon. 4. One great Reason why the Heat is tolerable, and the Places there habitable, is, that there are no long Days, but all near of the same length with the Nights; for if they were as long as in the *Temperate* and *Frigid Zones* they could not be inhabited, at least not easily. 5. The Winds much lessen the Sun's Heat. 6. Places have

have Summer and Winter at different Times, tho' in the ſame Climate, and near one another. 7. The Places that have Heat and Drought againſt the Sun's Courſe, are ſituated in the Weſt, having a Chain of Mountains on their Eaſt Side; excepting *Peru*. 8. The Seaſons in different Places obſerve no certain Law. 9. Moſt Inhabitants in the *Torrid Zone* count two Seaſons, as ſome Writers do, *viz.* wet and dry; yet there may be counted four, taking in a Spring and Autumn; for as with us the Spring comes near to the Nature of Summer, and Autumn to that of Winter; ſo may the dry Seaſons in the *Torrid Zone* be divided. 10. In ſome Places there is a continual Autumn, in others only twice in the Year, and in ſome only in one Part of the Year.

PROPOSITION XII.

To ſhow how the Seaſons are in the Temperate Zone.

1. IN this Zone the Cauſe, firſt mentioned, in the firſt Propoſition of this Chapter, *viz.* the Sun's approaching to, or withdrawing from, the Place, is ſo powerful, compared with other Cauſes, that it doth almoſt rule the Seaſons here of itſelf. For in the North Countries of the *Temperate Zone*, Spring and Autumn are while the Sun goes from *Aries*, by *Cancer*, to *Libra*, for then 'tis nearer them; then going from *Libra*, by *Capricorn*, to *Aries* again, 'tis Autumn and Winter; but in the South *Temperate Zone* 'tis quite the contrary: nor do other cauſes quite take away the force of this cauſe, as they do in the *Torrid Zone*.

2. YET the Seaſons differ in different Places, ſo as to make more cold or hot, rainy or dry Weather in one Place than in another, tho' both in the ſame Climate; yet they do not turn Winter to Summer,

Summer, nor Summer to Winter; for some Land is rocky, some boggy, some near, or far from the Sea; and some places sandy, others of Clay.

3. MOST Places near the Tropic are very hot in Summer; and some have a wet Season almost like that in the *Torrid Zone.* Thus in that Part of *Guzarat*, beyond the Tropic, there are the same wet and dry Months as within the Tropic, and the Summer is changed into wet Weather; yet there is greater Heat there, as the Sun's nearness requires, than in the dry part of the Year, when there is some Cold; and we judge not with us of Summer and Winter by dry and wet, but by Heat and Cold.

AND on the Shores of *Persia*, and in *Ormus*, there is so great Heat in Summer, from the Sun's nearness, that both Men and Women sleep all Night in Cisterns full of Water, and in *Arabia* 'tis as hot.

THRO' almost all *Barbary* (for so the Countries of *Africa* on the *Mediterranean* are called) after the middle of *October* there begins a raw Cold and Rain, as *Leo Africanus* relates; and in *December* and *January* the Cold is more intense (as 'tis every where in the *Temperate Zone*), but that is only in the Morning; nor do any then care for a Fire. In *February* the most part of Winter is over, but the Weather is so inconstant as to change five or six times in a Day; and in *March* the North and West Winds blows very strongly, and fill all the Trees with Blossoms, and in *April* the Fruits are all shaped; so that in the end of *April*, or beginning of *May* they have Cherries naturally, and in the middle of *May* they gather Figs from the Trees, and ripe Grapes are found in some Places in the middle of *June*; their Harvest Figs are pulled ripe in *August*: but these and the *Persian* Apples are most plentiful in *September*.

THE

THE Weather in no part of the Year is so unseasonable as not to have the three Months of Spring always temperate; they count their terrestrial Spring to begin the fifteenth Day of *February*, and to end the eighteenth of *May*; in which time they have always a pleasant Gale: if they have no Rain between from the twenty fifth of *April* to the fifth of *May*, they count it a bad Omen; they count Summer to last 'till the sixteenth of *August*, in which time they have a very hot and clear Air; they place their Autumn between the seventeenth of *August* and the sixteenth of *November*, and in these two Months their Heat is not so great: yet the Antients counted the Time between the fifteenth of *August* to the fifteenth of *September* to be the Baking Time of the Year, for then the Figs and Quinces, and such kind of Fruit were ripened, and their Winter they count begins the fifteenth of *November* and lasts 'till the fourteenth of *February*; and when it begins they begin to till the Plains, but not the Mountains 'till *October*. They are persuaded the Year hath always forty Days very hot, which begin the twelfth of *June*, and as many very cold, which begin the twelfth of *December*. The sixteenth of *March* and of *September* is their Day of Equinox; and the Day of Solstice is the sixteenth of *June* and *December*. They have great Winds in the end of Autumn, all Winter, and a good part of the Spring; and are much troubled with Hail, Lightning, and terrible Thunder; yea and abundance of Snow in many Places, which spoils their Corn, especially when it falls in the day-time, and the Corn is in Flower, as Pease, Beans, &c.

IN the Mountain of *Atlas*, which is thirty Degrees thirty Minutes North Latitude, they divide the Year only into two Parts; for they have a constant Winter from *October* to *April*, and from *April* to

to *October* again is their Summer; yet there is no Day in which the tops of the Mountains are not covered with Snow.

IN *Numidia* the Seasons of the Year pass away swiftly; for in *May* they gather their Corn, and in *October* their Dates; and from the middle of *September* there is a great Cold that lasts until *January*.

WHEN there is no Rain in *October* the Husbandman loses all Hope of sowing his Corn; and so also if *April* have no Rain. And *Leo Africanus* tells us, there are a great many snowy Mountains not far from the Tropic of *Cancer*.

THE North Part of *China*, tho' in a Latitude not greater than that of *Italy*, extending from thirty Degrees to forty two of Latitude, yet the Cold feels very sharp, says *Trigautius*, for the great Rivers and Lakes are frozen. The Cause of which is not sufficiently known, except we may say the Cold comes from the snowy Mountains in *Tartary* that are not far off: Which Cold they guard against by the Skins of large Foxes, and *Scythian* Martins, which abound there.

NEW *Albion*, tho' forty two Degrees North Latitude, and as near the Equator as *Italy*, yet is so very cold in *June*, that when *Drake*, the *English* Admiral, went there he was forced to go back to the South Part; the Mountains being then covered with Snow: the Cause thereof is the cold Constitution of the Ground, being stony.

IN *Eygpt*, which is bounded with the Tropic of *Cancer*, the Spring (as *Prosper Alpinus* tells in his Book of the *Egyptian* Medicine) and temperate Time of the Year is in *January* and *February*; and Summer begins in *March* or *April*, and lasts *June*, *July*, and *August*; and Autumn is in *September* and *October*; and the Winter in *No-*

vember and *December*. At the beginning of *April* they cut their Corn, and thraſh it immediately, and not an Ear is to be ſeen in the Fields after the twentieth of *May*, nor Fruit on the Trees, and the River begins to overflow the fifteenth of *June*.

IN the Streights of *Magellan*, and the adjacent Countries, tho' they have not a greater Latitude than we have; being fifty two Degrees South; yet their Summer is not very warm, ſo that the *Dutch* found, in a Bay in the Streights, a large Piece of Ice in *January*, which ſhould be the hotteſt Month with them; and on the Mountains on the Shore is ſeen Snow all the Summer: and it is found that in all the Countries of the South *Temperate Zone* the Cold is greater, and the Rains heavier, and in the Summer leſs Heat than in the North *Temperate Zone*. I doubt whether the Cauſe of it be, that the Sun ſtays longer in the north part of the Ecliptic, and moves ſlower there than in the ſouth part.

IN the Neighbourhood of the City of *Peru*, in the Province of *Potoſi*, there is ſuch a Cold that nothing grows for four Miles round it.

IN the Kingdom of *Chili*, which extends from thirty Degrees of South Latitude to fifty Degrees, the Spring begins in the Month of *Auguſt*, ſooner than it ought by the Sun's Courſe, and ends at the middle of *November*; and from that to the middle of *February* there is Summer; and then follows Autumn to the middle of *May*, when the Winter begins, which is very ſtormy and wet, and carries the Leaves from the Trees, and brings deep Snow, with great Froſt; which is ſoon melted by the Sun if it be not hid behind the Clouds for ſome Days, which is rare; but there ſeldom falls Snow on the Vallies; tho' it falls in great Quantity on high Places, and gathers between the Mountains in Heaps

Heaps as high as the Mountains, and continues there almost all the Year; and when it melts it swells the Rivers, which run violently to the Sea, and overspread the Land, which makes it very fruitful: but tho' it snow seldom in the Vallies, yet it is vehemently cold there, not inferior to that in many Places of *Europe:* partly because of the great Latitude, and partly from a subtle penetrating Wind that comes from the Mountains; which is sometimes insupportable, and makes the Places near the Sea more temperate.

THE Reader may find from Writers other Places different in their Seasons, tho' in the same Climate, or near it. For Example; the Air in *England* is not so cold as in *Holland* or *Germany:* so that the Cattle are not put into Stables in Winter. There is between *Tartary* and *Siberia*, a Place in the *Frigid Zone*, or the North part of the *Temperate* where are excellent Fields, pleasant Meadows, and scarce any Cold or Winter; where is built the City *Toorn*, which is now increased so as to repel the Insults of the *Tartars*.

IN *Japan*, which extends from thirty one Degrees to thirty nine, North Latitude, there is a cold, snowy, and wet Winter; when other Places in *Europe* of the same Latitude have not such severe Cold, because *Japan* is divided by several Streights and lies in the middle of the Sea.

IN *America*, and other Places near it, there is great Heat in Summer; for it lies among many little Hills: and the rich go in Summer to the Tops of them, and stay there for some Months; but the poorer Sort only go up in the Day-time, and come back in the Evening.

PROPOSITION XIII.

To show how the Seasons are, and what Day-light they have, in the Frigid Zone.

THE Causes of the Seasons and Day-light, delivered in the beginning of this Chapter, are thus in the *Frigid Zone*.

1. THE Sun's Center doth not rise above the Horizon for some Days, or Months, according to the Sun's Distance from the Pole.

2. WHEN the Sun is above their Horizon it sends it's Rays obliquely to them, while it revolves about the Horizon.

3. THE Sun does not go far under the Horizon, even in Places at, or near, the arctic Pole; and tho' it's Center doth not rise, yet it's Limb appears for some Days before the Center riseth; for the Sun's Semidiameter subtends an Angle of fifteen Minutes. For Example; Take a Place near the arctic Pole, whose Latitude is sixty seven Degrees, and elevate the Globe to that Latitude, and you will see, at the North Part of the Horizon, that no Degree of the Ecliptic, from the nineteenth of *Sagittarius*, to the eleventh of *Capricorn*, or the Sun's Center, at those Degrees will rise for twenty three Days, from the thirtieth of *November* to the Twenty first of *December*; and yet a Part of the Sun will be all that time above the Horizon. On the tenth of *December* the Limb touches the Horizon; thirtieth of *November* and twenty first of *December*, half of the Sun will be above the Horizon, and it's Center in the Horizon; and when it's Center comes to the fourteenth of *Capricorn* it will be all above the Horizon, about the twenty fourth of *December*; and so when in

in the ſixteenth of *Sagittarius*, or about the twenty ſixth of *November*.

BUT in Latitude ſeventy, or ſeventy five, the Difference between the riſing of the Center and it's Limb will be ſmall, ſcarcely one Day, or one Day and a half; for the Declination of the Sun doth then begin to inceaſe and decreaſe very faſt.

FROM this ſmall Depreſſion it follows, that they muſt have the Twilight before Sun-riſing, and after Sun-ſetting, for ſome Hours; and tho' the Sun riſe not for a whole Day, yet they will have the Light all or moſt Hours of the Day.

THERE is another Cauſe why the Sun is ſeen before it be elevated above the Horizon; *viz.* the Refraction of the Rays; of which we treated in *Chap.* xix.

AND not only the Sun appears ſooner, but the Twilight comes ſooner into the Air than it would do if there were no Refraction. We ſhall give an Example hereafter.

4. THE Moon when full, or nearly ſo, continues many Days above the Horizon, when the Sun continues under it; and the longer the nearer the Place is to the Pole: yet it is not ſo high as to afford any Heat. But when the Sun continues above the Horizon for a whole Revolution, the full Moon is never above it.

5. THEY have almoſt always the ſame fixed Stars above the Horizon; but not the ſame Planets. *Saturn* is above it fifteen Years in Places near the Pole, and fifteen below it; and *Jupiter* ſix above and ſix below it; *Mars* one Year; *Mercury* and *Venus* about half a Year, from whence may ariſe great Difference in the Seaſons there.

6. THE Land is rocky or ſtony in moſt Places; and but in few Places ſulphureous, fat, bituminous, or of Clay: in the former Caſe, the

Land is ſomething barren, and in the later moderately fertile.

7. THESE Places are ſurrounded with Sea. We know little of the inland Parts.

8. SOME Countries in the *Frigid Zone* have pretty high Mountains; and ſome have none at all, but are ſtretched out into large Plains.

9. THERE frequently blow cold Winds from the Pole; the Eaſt Wind is rare, and the Weſt more rarely found there. In the cold arctic Circle the North Winds rage; but in the antarctic the South Winds.

10. THEY have frequent Clouds and Rain.

FROM hence one may eaſily judge what Seaſons they have; for in Winter, when the Sun doth not riſe for ſome Days it muſt be dark, cloudy, cold, and froſty, that cauſes the Places to be uninhabited; but they are not quite without Light then, the Moon being long above the Horizon: and there will be ſome Twilight from the Sun in moſt Places, tho' both theſe Cauſes may be hindered by Snow, Clouds, and Rain; for when the groſſer Clouds are not diſſipated by the Sun, they continue near the Horizon, and one cannot ſee far. There is nothing growing there. What ſome ſay of the Land being more fertile, and the Air leſs cold nearer the Pole, does not ſeem probable; for neither in *Nova Zembla*, which is but ſixteen Degrees from the Pole; nor *Spitzberg*, which is but eight Degrees, is there any ſuch thing; but rather Snow, Rains, and cold Winds in the very middle of Summer: nor doth it avail, that Sailors have found in Latitude eighty two, in *Greenland*, as they ſuppoſe, that the Graſs was green, and the Cold leſs than in *Nova Zembla*; and that no other Beaſts are found there but the *Rain-Deer*, a Species belonging to theſe North Countries. Theſe Deer are ſo

fattened in one Month with the Herbs there that their Flesh tastes deliciously.

BUT seeing there are no more Examples of that kind in the *Frigid Zone*, we must not make a general Rule from it; especially seeing a Reason may be given peculiar to that one; the Land being boggy and moorish; and the Herbs not so much Land-herbs as Sea-weeds; which are fattening to the Deer, there being no other Herbs nor any Trees on the Spot. The Land contains a fat sulphureous Substance, which being mixed with Sea Water or River Water, brings forth such fat and oily Herbs; and the like Ground is not found in other Places, but rather the quite contrary.

IN these Places therefore there is little Light, but great Snows, Showers, Cold, and Winds from the Pole; which begin when the the Sun enters *Capricorn*; tho' in Autumn, when the Sun is going from the first of *Libra* to the first of *Capricorn*, they rage almost as much: but in Spring the cold Weather is more temperate, yet not without Snow, Rain, and cold Wind from the Pole. The Cold begins to be moderate as the Sun goes from the first of *Aries* to the first of *Cancer*; and in that time, or after, the Sun is above the Horizon for whole Days; when the Heat begins; but 'tis not so great as to melt all the Snow, much less the Ice. Wherefore Seamen tell us, there are Snows and Ice that have lain in that Country for ever. Their Summer is from the Sun's entring the first of *Cancer*, to it's coming to the first of *Libra*; in the former Part of it, the Sun is also whole Days above the Horizon, and thereby increases the Heat a little: so that *June*, *July*, and *August*, are more mild; and in some Places the Heat is considerable among the Mountains. But this is often hindered by Rains and Clouds, and cold North

Winds, and ſometimes Snow; ſo that no Corn can ripen, except in ſome Places near the arctic Circle.

THAT the Reader may the better judge of theſe Things, it will not be amiſs to give ſome Account of what the *Dutch* obſerved in the *Frigid Zone*, when ſailing the Streights of *Waygat*'s and *Nova Zembla*: for Students may therein find ſomething to make them better acquainted with the uſe of the Globes.

JUNE 13. 1594. *New Style*. About ſix Miles from *Nova Zembla*, when the Sun did not ſet, they meaſured it's leaſt Altitude at twelve at Night, and found their Latitude ſeventy three Degrees twenty five Minutes.

OTHERS obſerved the ſame Day, but in Latitude ſeventy ſeven Degrees twenty Minutes, a great Quantity of Ice, which ſeemed to cover the whole Sea, ſo far as they could ſee from the top Maſt.

ON the twenty firſt of *Auguſt* they could not paſs thro' the Streights of *Waygat*'s for the great Quantity of Ice that came from the *Tartarean* Sea, and that thro' the whole Summer; ſo that they were forced to return without doing any thing.

IN another Voyage they found, on the fifth of *June*, the meridian Altitude in the North one Degree; from which their Latitude was ſeventy four Degrees; and the Sea was covered with Ice.

ON the nineteenth of *June* they found, from the Sun's Height, their Latitude eight Degrees eleven Minutes, about *Greenland* or *Spitzberg*. The *Engliſh* ſurveyed the Shores to Latitude eighty two Degrees; but found the Sea in the middle of Summer ſo bound up with Ice, that it ſeemed to be a part of the Land; and there was a thick Cloud, or groſs Vapour above the Sea, ſo that they could not ſee far.

ON the eleventh of *Auguſt* 1596, in Latitude ſeventy ſix, about *Nova Zembla*, they found Ice that

that reached to the bottom of the Sea; and on the twenty seventh Day they found their Ship so surrounded with Ice, that they were forced to Winter there, without seeing the Snn.

ON the twenty sixth of *September*, the Cold was so severe that they could scarcely endure it: and the Snows were constant; and the Earth was so bound up with Frost that it could not be dug; nor could they thaw it with Fires.

ON the first of *September* the Sun appeared a little in the South Meridian, above the Horizon; and the full Moon was elevated in the North, and was seen going round above the Horizon.

ON the second of *November* they saw the Sun rise South South-East; tho' it did not rise wholly, but went along in the Horizon to South South-West.

ON the third of *November* they saw the Sun rise South and by East; that is a Part of it, tho' they could see it all from the Top of the main Mast.

ON the fourth of *November*, tho' the Air was calm and clear, yet they could not see any of the Sun; but the Moon was then seen for whole Days being at the Full; and the Cold was most vehement: and after that, no Fire could warm them, and the Snows and Winds were fierce.

ON the ninth, tenth, and eleventh of *December* the Air was clear; but so cold that our Winter was not to be compared with it; and the Stars were so clear that it was pleaseant to see them revolve.

THE Sun did not rise all that time; yet they had some Twilight, in the South especially: for there they have most Twilight at twelve o'Clock; which makes their Day in the Winter.

ON the thirteenth of *January* the Air was clear; and from that time they found a sensible increase in

in the Twilight, and ſome diminution of the Cold, and a ſmall Heat at Mid-day.

ON the twenty fourth of *January* the Air was alſo clear; and then they firſt ſaw the Limb of the Sun in the South; and afterwards the whole Sun above the Horizon.

ON the ſecond of *May* a ſtrong Wind removed the Ice from certain Places; in the Sea, they had a ſmall Heat ſome Days, but moſtly cold Winds, Snow, and Showers.

IT is remarkable in theſe Obſervations, that the Sun left them the ſecond of *November*, which by Refraction (that makes it appear nineteen Days ſooner) ſhould not have been ſo ſoon. It ſeems the Difference in the Atmoſphere may cauſe ſomething of this; for the Sun coming to the Horizon after three Months abſence, the Air was there thicker and groſſer than it was in the former Year; when the Sun had been long under the Horizon. Yet I doubt whether the Diverſity of the Air can cauſe it to diſappear ſo many Days ſooner; and it was otherwiſe obſerved by thoſe in 1634, when they wintered at *Spitzberg*: for the Sun did then leave them the ninth of *October*, and after a long abſence appeared again the thirteenth of *February* 1634; and theſe two Days are almoſt equidiſtant from the eleventh of *December*. And in the laſt of the two Obſervations, they might eaſily err a few Days; for being in their Bed they did not obſerve the Sun riſe on the tenth, eleventh, and twelfth of *February*: or ſome Clouds or Rain might hinder their ſeeing it.

CHAP.

CHAP. XXVII.

Of the Shadows which upright Bodies cast when enlightened by the Sun; and of the Divisions of the Earth that arise therefrom.

SEEING Bodies in different Places of the Earth cast shadows which are directed to different Points; and that other Varieties are observed therein; Men have admired hereat, as not knowing the Cause. And the Inhabitants of the Earth are thereby divided into three Sorts; which Division is also applied to the Parts of the Earth's Superficies they inhabit; whence some are called *Amphiscii*, others *Heteroscii*, and the rest *Periscii*; which we shall explain a little, tho' it belongs not directly to Geography.

SHADOWS take their Denominations from the Points they are stretched out to, as the *Oriental* Shadows, or *Occidental*, from the Sun's being West or East; but we are to consider those chiefly that are in the Plain of the Meridian; from upright Bodies, the Sun being in the Meridian: and these are either North or South.

THE *HETEROSCII* are those that have the Shadow of upright Bodies tending to the North or South, every Day of the Year.

PERISCII are those that have such Shadows going round to all Points in one Day.

AMPHISCII

AMPHISCII are thoſe that have ſuch Shadows tending to the North ſome Days; and in other Days to the South. But not to exclude Places in the Tropics, for this laſt kind we ſubſtitute the *Aſcii*, who on a certain Day of the Year have no Meridian Shadow; and theſe are either 1. *Amphiſcii*, that have no Meridian Shadow on two Days of the Year; or on ſome Days that Shadow tends to the North, and on other Days to the South: or, 2. They are *Heteroſcii*, who on one Day have no Meridian Shadow; and on the other Days the Shadow is always ſtretched to North or South.

PROPOSITION I.

The Shadow of upright Bodies tends to a Point oppoſite to that in which the Sun is.

THOSE that are ſkilled in Optics and Dialling tell us, that the Shadow, the dark Body, and the luminous Body are all in one Plain; and the end of the dark Body of the Shadow, and the luminous Body are in one Line; for the erect Body and it's Shadow with a Line from their two Extremities, conſtitute a Triangle, the three Sides of which muſt be in one Plane; and the Body being upright, the Plane thro' it muſt be ſo alſo; and thus in a vertical Plane. And becauſe the upright Body is between the Sun and the Shadow, theſe two muſt be in oppoſite Points.

THERE are three Parts in the Shadow; 1. The dark Part, which is terminated by a Line from the upper Part of the Limb. 2. The central Shadow, intercepted between the Ray from the Center, and that from the upper Limb. And, 3. the *Penumbra*; between the central Ray, and the Ray from the inferior Limb.

PRO-

PROPOSITION II.

Those that live under the Tropics are Ascii-Heteroscii.

FOR when the Sun is in the Tropic of *Cancer*, or *Capricorn*, upright Bodies have no Shadows; but when the Sun goes nearer the Equator, the Shadow is projected to the North or South.

PROPOSITION III.

Those that live in the Torrid Zone *are* Ascii-Amphiscii.

FOR take any Point on the Globe, in that Zone; and the Sun will be twice in the Year in the Zenith of that Place; and so there will be no Shadow of upright Bodies. But in other Days the Shadow is projected either to the North, if the Sun be to the South of them; or to the South, if that be to the North of them.

PROPOSITION IV.

Those in the Temperate Zone *are* Heteroscii.

FOR the Sun all the Year is still more southerly from those in the North *Temperate Zone*, and more northerly from those in the South *Temperate Zone*; whence the Shadow must always tend North to the one, and South to the other.

PROPOSITION V.

Those in the Frigid Zone *are* Periscii.

FOR the Sun doth not set to them for some Days, but revolves above the Horizon; so that the Shadow must turn round with it.

PROPOSITION VI.

A Place being given in the Torrid Zone, *to find when the Inhabitants there will be* Ascii.

FIND when the Sun will be vertical to that Place, and there will be two Days when they will have no Shadow; as in *Prop.* iii.

PROPOSITION VII.

The Day of the Year being given, to find those Places where the People are Asciii, *or without Shadows.*

FIND the Places that the Sun is vertical to that Day, by *Chap.* xxiv. *Prop.* ix. and those are the Places.

PROPOSITION VIII.

A Place being given in the Frigid Zone, *to find when the People there are* Periscii.

FIND when the Sun will not set to them, by *Prop.* x. *Chap.* xxiv. and those are the Days.

PRO-

PROPOSITION IX.

The Day being given, to find where the People in the Frigid Zone *will be* Periscii; *and that the first Day.*

FIND the Places where the Sun begins not to set; and you have the People there.

PROPOSITION X.

Those under the Equator have the Shadow one half of the Year to the North of them, and on the other half to the South of them: and on the two Days of the Equinox they are Ascii, *or without Shadow.*

THIS needs no Explanation.

PROPOSITION XI.

To place an horizontal Plane so as an upright Style on it have no Shadow some Days; and on other Days project one either to the North or South, as it is with those in any given Place of the Torrid Zone.

SUBSTRACT the Latitude of that Place, from the Latitude of your Place (but add if of different kinds), and what Degrees remain make your upright Style bend so many southward from the Perpendicular; and the Plane to which the Style is perpendicular, bending along with it, will be the Plane on which Shadows will be projected as on the horizontal Plane in that Place of the *Frigid Zone.*

PROPO-

PROPOSITION XII.

In Places under the Equator the Shadow of an upright Style is in one right Line, all the equinoctial Days, being on the West Side of the Style in the Forenoon, and on the East Side in the Afternoon; but on other Days the Shadow turns in a Semicircle.

IN Places in the *Torrid Zone*, while the Sun is between the Tropic and the Parallel in which the Place lies, the Shadow describes less than a Semicircle; and in Places in the *Temperate Zone*, while the Sun is in the South Part of the Ecliptic, the Shadow describes also a less Space than a Semicircle; but in the North Part a greater Space, and in the Equinoxes the Shadow is carried thro' a Semicircle, excepting in the Equator, and at the Pole.

THESE may all appear by in inspection on the Globe; or by describing a Figure.

PROPOSITION XIII.

In Places in the Torrid Zone, *while the Sun is between the Parallel of the Place and the Tropic nearest to it, the Shadow then goes back twice, repeating the Directions to the same Points, once in the Forenoon, and once in the Afternoon: and the Sun will then seem to go back.*

ELEVATE the Globe to a Latitude less than thirty three Degrees thirty Minutes; and describe the Parallel of that Latitude. I say while the Sun is between that and the Tropic, the Sun and the Shadow will seem to go twice back; and to repeat the same Directions. Apply the Quadrant of Altitude to the Zenith, and turn it about 'till it touch

the Parallel, in which the Sun is drawn on the Globe; and bring the Point of Contact to the East of the Horizon. From the Sun in that Point draw a Line to the Zenith of the Place, and it will cut the Line of the Sun's Course in a Point higher above the Horizon, where the Sun will direct the Shadow the same way as when it was rising; having had other Directions repeated between these two. And the same will be on the West side of the Sun's Course, where it will set in the same Point it was in a few Hours before.

THIS will appear also in *Fig.* 32. Suppose a Place in the *Torrid Zone*, as L, in which there is a Style erected; and let AMF be the Tropic, or the Sun's Parallel; and let the Sun be rising in A: then the Shadow of the Style is projected in the Line L *a*; and when the Sun comes to C the Shadow will be in the Line L *c*, and when it comes to G it will be again in the Line L *a*, and when it comes to the Meridian in M, the Shadow is directed South in the Line L *m*, and when it is in E, and sets in F, it will again have the same Direction.

COROLLARY.

'TIS no Miracle that Shadows go back on Dials, except they go back on a sudden; or if they Point back to the same Hour-Lines, if the Style be not perpendicular, but parallel to the Poles: and tho' it be perpendicular, yet the Line of Shadows doth not show the Hour, except the Plane of the Dial be in the equatorial Plane.

PROPOSITION XIV.

A Plane being given in the Torrid Zone, *and one of those Days in which the Sun and Shadow seem to go back; to find the Point in which the Sun then is, and the Hour when it will be.*

ELEVATE the Globe for the Latitude, and mark the Sun's Place in the Ecliptic, and draw with Chalk it's Parallel that Day; and applying the Quadrant to the Zenith, turn it about 'till it touch the Parallel, and it will be on that Point.

AND to find the Hour, observe the Point of Contact, bring the Index to 12 on the horary Circle, and bring the Point to the Meridian, and the Index will show how many Hours the going back begins before or after Noon.

PROPOSITION XV.

The Lengths of the Shadows decrease as the Sun rises above the Horizon; and, vice versâ, *increase as the Sun goes from East to South; and again decrease as it goes from South to West.*

FOR the Sun, the higher it is, comes nearer to the Zenith of the horizontal Plane; and therefore the Ray that terminates the Shadow comes nearer the Style of the Dial; and the Shadow thus becomes shorter: and the Sun being at the greatest Height on the Meridian, the Shadow must be shortest; and in the Horizon it hath no Altitude; and therefore the Shadow is infinite.

PRO-

PROPOSITION XVI.

Having the Altitude of the Style and Length of the Shadow, to find the Sun's Altitude; and from thence the Hour; if the Latitude and Day of the Month be known.

THE Length of the Style, the Shadow, and the Ray that terminates the Shadow, make a right angled Triangle; and, according to *Prop.* xv. *Chap.* ii, make this Proportion: As the Length of the Shadow is to the Length of the Style, ſo is the Radius to the Tangent of the Angle of the Sun's Altitude. Then find the Hour by *Prop.* iii. *Chap.* xxix.

PROPOSITION XVII.

Having the Semidiameter of the Sun and Earth, to find the Length of the Shadow which the whole Earth caſts in the Heavens.

THE Shadow of the Earth is conical, as they that are ſkilled in Optics demonſtrate; and may be eaſily ſhewn by a Figure. Therefore we are to find the top of the Cone, (which comes on the Moon when eclipſed) how far it is from the Center of the Earth; thus: As the Difference of the Semidiameter of the Sun and Earth, is to the Sun's Diſtance from us; ſo is the Semidiameter of the Earth, to the Length of the Earth's Shadow, or of the Axis of the conical Shadow.

PROPOSITION XVIII.

Having the Distance of the Moon from the Earth, and the Length of the Earth's Shadow; to find how much of the Moon will be dark when she is eclipsed, in the Ecliptic itself.

BY the *Rule of Three*; As the Length of the Shadow is to it's Excess above the Moon's Distance; so is the Semidiameter of the Earth, to the Semidiameter of the conical Shadow, where the Moon enters it.

THEN, As the Distance of the Moon is to this Semidiameter of the Shadow; So is the Radius of the Tangent of the Angle, at the Eye subtended by that Semidiameter: which being doubled, gives the Angle opposite to that Diameter of the Shadow; with which compare the Angle opposite to the apparent Semidiameter of the Moon at the Eclipse; and from thence may be known how much is dark: which if you desire in Digits (as Astronomers use to express the Quantity of the Eclipse, and the apparent Semidiameter of the Moon which seems to be about twelve Inches, or Digits, in Breadth) say, As the Diameter of the Moon is to twelve Digits; so is the apparent Semidiameter of the Shadow to the Digits darkened.

PROPOSITION XIX.

The further a Place is any Day from the Equator, or from the Parallel in which the Sun is, the larger the Shadow is at twelve, and other Hours.

BECAUSE the Sun is further from the Zenith of those Places; therefore the Ray that terminates the

the Shadow, is farther from the Style; and so the Shadow longer.

PROPOSITION XX.

If there be placed a Style above any Plane, so as to look the same Way as the Axis of the World doth, or be parallel to it; the Shadow of it will fall on that Line of the Plane which is cut by the meridian Circle in which the Sun then is.

FOR the Shadow of the Axis, or Style, falls in the Plane of the Meridian Circle: because the Sun, the Style, and Shadow, are all in one Plane, as was said in *Prop.* i. but as the Shadow falls also on the Plane that it is raised on, it must fall in the Line of common Section of the Plane and meridian Circle.

PROPOSITION XXI.

To describe an Equinoctial Dial.

LET the Plane either of Wood, Brass, or other Matter, be raised above the horizontal Plane, according to the Complement of the Latitude of the Place.

BUT it is better first to draw the Hour-Lines on the Plane thus: Describe a Circle, which divide into twenty four Parts, and draw Lines from the Center to each Part; any one of these Lines may be taken for 12 of the Day; but if the Latitude of the Place be small, there is no need to draw the Hours for Night, when the Sun is under the Horizon: upon the Center erect a perpendicular Style; this Dial being raised, so that the Plane of it shall be in the Equator, the Sun shines the one half of the Year above, and the other, in Winter,

ter, below; and therefore the Hour-Lines must be on both sides.

FOR the fixing of it you must find the Hour of the Day, and cause the Shadow to come on that Hour; or else you must find a Meridian Line, which the Style is to be raised above.

ON this Dial may be drawn several concentric Circles, which will shew the Sun's Place and Declination: Thus, divide the Style in 100 Parts, which being the Radius of a Circle, take the Complement of the Declination, 5 *Degr.* 10 *Degr.* 15 *Degr.* &c. and with the Tangent of these Degrees describe concentric Circles; and when the end of the Shadow of the Style comes into one of them, it shows the Declination and the Sun's Place, which may be marked on the Circles.

PROPOSITION XXII.

To describe a Dial on an horizontal Plane.

BY the Globe. Elevate the Globe to the Latitude of the Place, and bring some remarkable Meridian under the Brass Meridian, and the Index to 12; then turn the Globe till the Index point to 1 or 11, and observe how many Degrees on the Horizon the point in which the Meridian cuts the Horizon is from the North; and so many Degrees must the 11th Hour, or the Hour of one, make with the Meridian: then, the same way, make the Index, by turning the Globe, to point to 2 or 10, and you'll have the Degrees for those Hours, on the wooden Horizon, between the Point where the Meridian cuts the Horizon and the North.

THEN set the Style from the Center of the Dial above the meridian Hour of 12, and elevate it according to the Latitude of the Place; or ra-

ther make a right angled Triangle, whose acute Angle at the Base shall be equal to the Latitude; which being first made of Paper may be afterwards of Brass or Iron, and set upright in the meridian Line. This may be better done without the Globe; which will be easier apprehended by seeing it done, than many words.

PROPOSITION XXIII.

To describe a vertical Dial, whose Plane shall be due East or West.

THE Plane of the Dial being thus in the Meridian, draw a Line, elevated according to the Latitude, which will be the Line of 12, to those 90 *Degr.* East or West from you, as your Plane is directed; but it will be the sixth Hour to you: then cut that Line by another in the middle at right Angles, and on it set the Tangent Degrees found by the Globe, from the first Line both ways, and draw thro' these Points Hour-Lines parallel to the first Line, and the Style being parallel must be as broad as three Hours is distant from the first Line. *Note*, if the Vertical be due South or North, you make the Dial on it as in *Prop.* xxii. only the Style must be raised according to the Complement of the Latitude.

PROPOSITION XXIV.

To find by our Dial the Hour at another Place, tho' ever so remote from us.

IT must be considered, whether the other Place be to the East or West; if to the East, they have 12 before us, if to the West after us. Find by the Globe the difference of Longitude between the

two Places, which turn to Time, allowing 15 *Degr.* for an Hour; and add or ſubtract that Time from the Hour with us, as the Place is Eaſt or Weſt: their Hour-Lines may be alſo drawn on your horizontal Dial, as in *Prop.* xxii.

PROPOSITION XXV.

To elevate a Plane above our Horizon, and to draw a Dial on it, in which the Shadow will ſeem to go back, as in Places of the Torrid Zone.

WE ſhall chuſe here the Elevation of 10 *Degr.* above the Horizon of the Place in the Torrid Zone; then in our Latitude, 52, the Plane muſt be raiſed 42, and the Pole will be 10 *Degr.* above it; then make a Dial on that Plane for the Latitude 10, by *Prop.* xxii, and put out the ends of the Hour-Lines next the Center, and erect an upright Style, a little from the Center, on the meridian Line, ſo high as it would reach to the back of a Style that looks to the Pole, and the end of the Shadow of the erect Style will ſhow the Hour, and ſeem to go back on ſome Days, as we ſaid above. All other kinds of Dials may be made by the Globe; but becauſe this belongs to *Gnomonics* we ſhall not treat further of it.

CHAP. XXVIII.

Of comparing the Celestial Appearances in different Places of the Earth.

FROM the Consideration of the Agreement and Disagreement of the celestial Appearances in different Places, there arise different Denominations of the Inhabitants, tho' they are not of different sorts; some being *Antœci*, others *Periœci*, and others *Antipodes*.

ANTOECI are those that live in the same Semicircle of the Meridian; but on different sides of the Equator, and at equal Distances from it.

PERIOECI are in the same Parallel, but in different Semicircles of the Meridian: sometimes all the People in one Parallel are called *Periœci*; but we shall not take it so, to avoid Confusion.

ANTIPODES are those that are diametrically opposite to one another.

NOTE, these three Names do for the most part signify the People in both Places, as we explained them; tho' sometimes they denote only those of one Place, as when we say such People are *antœci* or *antipodes* to others.

PRO-

PROPOSITION I.

Those that live in the same Semicircle of the same Meridian, have all the same Hours at the same Time.

FOR when the Sun comes into that Meridian, 'tis twelve at Noon, in all the Places in that Meridian; and therefore they must have all other Hours at the same Time; seeing the Sun's going from their Meridian to another Meridian fifteen Degrees from it makes an Hour; which is the twenty fourth Part of the Revolution to them both.

PROPOSITION II.

They that live on different Sides of the Equator, have different Seasons of Summer, Winter, Spring, and Autumn, at the same time.

FOR the Summer begins in a Place according to the Sun's Course, when the Sun is nearest to it's Zenith: and the Winter begins when the Sun is furthest from it: and because the Sun goes from the North Hemisphere to the South: contrariwise, as it leaves the one, it comes nearer to the other; and therefore 'tis Summer in one Place, the same Time that 'tis winter in the other. The Changes in the Seasons in the *Torrid Zone* have something peculiar to them, as in *Chap.* xxvi.

PRO-

PROPOSITION III.

They that are in the North Hemisphere have, as they look to the Equator, the East on the right Hand, and the West on the left, the South before them, and the North behind them; but they that are in the southern Hemisphere, have the Stars rising on their right Hand, and setting on the left, as they turn their Face to the Equator.

THEY that live on the Equator have the East on their right Hand, and the West on the left while they look to the North, but contrariwise if they look to the South.

THEY that are in the North Hemisphere when they look to the Equator, the Sun will seem to rise and set behind them, while 'tis in the northern Signs; but when in the southern Signs, it will appear to rise and set before them: and the contrary will happen if they turn their Faces to the Poles.

SAILORS, and others who understand not these things, wonder at them; when they come to the South Hemisphere: but they appear plain from the Globe.

PROPOSITION IV.

The Celestial Appearances to the Antœci *are these.*

1. THEY have Mid-day and Mid-night, and all the Hours at the same Time; as in *Prop.* 1. of this Chapter.

2. THEY have contrary Seasons at the same Time; when 'tis Summer with the one, 'tis Winter with the other; and so as to Spring and Autumn.

3. THE Days of the one are equal to the Nights of the other; and the Nights of the one to the Days of the other.

4. WHEN the Days of the one increase to the longest, the Days of the other Place decrease to the shortest; for the Days that are opposite to one another in the Calendar, they have them equal; that is, the twentieth of *April* in the one, to the twentieth of *October* in the other.

5. ON the equinoctial Days the Sun rises and sets at the same Time, but on other Days sooner to one than the other; and these two Days the Sun hath the same Altitude in both Places: but each Hour in the Day on other Days, the Altitude differs.

6. WHEN they look towards one another, the Sun and Stars seem to rise and set on different Hands.

7. WHEN the Sun rises and sets before the Face of the one, it doth so behind the other; and contrariwise.

8. THEY have different Poles elevated equally.

9. THE Stars that never set to the one, are never seen by the other; and contrariwise. These are all plain on the Globe.

PROPOSITION V.

The Inhabitants of the Equator have no Antœci, *and their* Periœci *are the same with their* Antipodes.

THIS is plain from the Definitions we gave of them.

PRO-

PROPOSITION VI.

A Place being given on the Globe, to find who are the Antœci, Periœci, *and* Antipodes *to the Inhabitants there.*

FIND the Latitude of the Place by bringing it to the Brass Meridian; and their *Antœci* will be in the same Latitude, on the other side of the Equator.

BRING the Index of the lower Circle to 12, and mark the Point in the Meridian above the Place given; and also mark the Point above the *Antœci* of that Place: then turn the Globe till the Index point to the other twelfth Hour, and you will have the *Periœci* under the first marked Point of the Meridian, and the *Antipodes* under the other.

PROPOSITION VII.

They that live in the same Parallel, have all the Days and Nights of the Year equal; and each Star continues the same Time above their Horizon: and the same Stars never rise to them, and the same never set. The Sun and Stars all rise and set on the same Point, and each Star is at the same Hour equally under or above the Horizon: they have the same Pole equally elevated, and the Stars rise and set on the same Side to both, when they turn their Face to the Pole or the Equator, and have the same Seasons at the same Times, excepting some Things peculiar in some Places.

THESE Things are manifest from the Consideration of the Stars, and the Situation of the Places on the Globe. If you elevate it to the Latitude of one Parallel, the wooden Horizon will be the Ho-

rizon of all the Places in that Parallel; which will make the Proposition plain.

PROPOSITION VIII.

The Celestial Appearances of the Perioeci *are these.*

1. ALL those Particulars agree to them which we mentioned in the preceding Proposition of the Inhabitants of the same Parallel.

2. THEY have Hours, which tho' nominally the same, yet are really contrary; for when 'tis twelve at Day with one, 'tis twelve at Night with the other; and 'tis two after Mid-night with the one, when 'tis two after Mid-day with the other, *&c.*

3. ON the Equinoctial Days the Sun sets to one, while 'tis rising to the other; and so Night-time to the one, is Day-time to the other; but in the Half of the Year, when the Sun goes thro' the Semicircle of the Ecliptic next to them, that is, in Spring and Summer, it rises first to the one, before it rises to the other; and therefore they have Day, or the Sun-shine, for an Hour, or part of an Hour, at the same Time; *i. e.* while 'tis setting in the West to the one, 'tis rising in the East to the other; but when the Sun is in the other Half of the Ecliptic, *i. e.* in Autumn and Winter, it sets to the one before it rises to the other: And so they have no Day but a Part of Night common to both, and the Sun for some Time under their Horizons; yet so as to begin Night with the one, and end it with the other.

4. THEY may both, the same Way, see those Stars that decline from the Equator to the Pole, elevated to them at the same time for some Hours, or Parts of an Hour, *i. e.* before they set to one, they rise to the other, and contrariwise: and that the

the longer, the further the Star be from the Equator; but those Stars that decline from the Equator to the Pole under the Horizon, they never see, at the same Time; for they set to the one, before they rise to the other: and therefore for some Hours, or Parts of an Hour, they are seen by neither of them; and the longer Time, the nearer the Star is to the Pole. Those that are always seen by the *Antœci*, are always hid to the *Periœci*.

5. THAT Part of the Earth which one of the *Periœci* hath on the West, the other hath on the East.

PROPOSITION IX.

The Celestial Appearances compared together, with regard to the Antipodes, *are these.*

1. THE Sun and Stars rise to the one, when they set to the other, all the Year round; for they have the same Horizon.

2. THE Day of the one, is the Night of the other.

3. THE opposite Days in the Year are equal, and also the Nights; so that when the one hath the longest, the other hath the shortest.

4. THEY have contrary Seasons at the same Time; and the same at different Times.

5. THEY have different Poles, equally elevated; they are equally distant from the Equator, but have it on different Points; they are in the same Meridian, but different Semicircles of it.

6. THEY have Hours nominally the same, tho' really contrary; 'tis Mid-day to one, when Mid-night to the other.

7. THOSE Stars that are always above the Horizon of the one, are always under the Horizon of the other; and they that are long above the Horizon

rizon of the one, are a short Time above with the other.

8. THE Sun and Stars seem to rise on the right Hand to the one, and on the left to the other, when they both look to the Horizon; and if the one have the Sun before or behind, for half a Year or more, the other hath it as long.

PROPOSITION X.

The Periœci *of one Place, are the* Antipodes *of their* Antœci.

AND thus the *Antipodes* of one Place are *Periœci* to the *Antœci* of that Place. This needs no Proof.

PROPOSITION XI.

A Place being given on the Globe, to find where the People have Mid-day, and all the Hours at the same Time; and to find where the Hours are contrary to the Hours in that Place.

BRING the Place to the Brass Meridian, and all Places under it count the same Hours; then bring the Index to 12, and turn the Globe till it come to the opposite 12, and the Place under the Brass Meridian will shew where they count contrary Hours to those of the given Place.

PROPOSITION XII.

A Place on the Globe being given, to find the Places where all the Days of the Year are equal to the Nights of the former Place.

BRING

BRING the given Place to the Meridian, and find the Parallel of the *Antœci*; then will all the Places in the Parallel answer the Question.

BUT if the Place be sought, in which the Days are equal to the Nights of a given Place, and all the Hours the same; then the Place of the *Antœci* is the Answer.

AND if all the Hours must be contrary, then the Place of the *Antipodes* is the Answer.

PROPOSITION XIII.

Having a place on the Globe, and the Day of the Year to find the Hours when the Inhabitants of that place, and their Antœci, *can see the Sun at once; and the Hours, or Parts of an Hour, that the one will see the Sun sooner than the other.*

FIND, by *Prop.* iv. *Chap.* xxv. the Length of the Day there at that Time, what that Length wants of twenty four Hours, are the Hours in a Day with the *Antœci*; for so many Hours they have the Sun above the Horizon an once, as their Day is long: if the Place be in the Equinoctial, they have each twelve Hours Day; if not, the one of the *Antœci* has more than the other: or thus, if the Length of the Day in the Place given be less than twelve Hours, then the *Antœci* will see the Sun for that Time and more, both before and after that Time; but if the Length of the Day be more than twelve Hours there, then you must take the Hours at Night, and so many the *Antœci* will see the Sun at once: and these Hours are near the Meridian in both Places, the Half before, and the other Half after, for they have the Sun in their Meridian at once.

THE difference of Days, or between the Nights and Days, in the same Place being halved, shows the

Hours that the Sun riseth sooner, or sets later than in the other Place.

PROPOSITION XIV.

Having a place on the Globe, and the Day of the Year, to find the Time that the Inhabitants, and their Periœci, *will see the Sun at once; and how long they cannot see it together.*

FIND the Length of the Day and Night at that Time in that Place; then the half of their Difference is the Time that the Sun rises sooner to the one, than it doth to the other; and sets to the one, before it rises to the other.

CHAP.

CHAP. XXIX.

Of comparing the Times in one Place with those of another.

PROPOSITION I.

Having the Hour in one given place, to find the Hour of another place given.

THE Place for which the Hour is given being brought to the Brass Meridian, and the Index to 12, turn the Globe till the other Place come under the Brass Meridian; and the Index will point to the Hour in the other Place.

PROPOSITION II.

Having the Hour in any place given, to show all the places on the Globe, in which 'tis then Mid-day or Mid-night, or any Hour you please. The Problem should be proposed and solved of the Earth itself, it being a Property of the Earth, if we were to proceed scientifically; and this we understand of many of the following Problems.

BRING the Place to the Meridian, and the Index to the Hour of the Place; then turn the Globe till the Index points to 12, and you see under the upper Part of the Brass Semicircle, all the Places where 'tis Mid-day, and in the lower Part

where 'tis mid-night: and for any other Hour turn the Globe till the Index point to it, and you have the Places where 'tis ſuch an Hour under the Braſs Meridian.

PROPOSITION III.

Having the Altitude of the Sun, the Day of the Year, and the Latitude of the place, to find the Hour for that Altitude.

ELEVATE the Pole for that Latitude, and find the Sun's Place in the Ecliptic, and bring it to the Meridian; then fixing the Quadrant of Altitude at the Zenith, and the Index at 12, move the Globe and the Quadrant till the Sun's Place come under the Degree of Altitude marked on the Quadrant; and the Index will point to the Hour.

PROPOSITION IV.

Having the Point the Sun is in at any Hour of a given Day, and the Latitude of the place, to find the Hour.

WORK as in the preceding Propoſition, and bring the Quadrant to the Point, and the Sun's Place under the Quadrant, and the Index will ſhow the Hour. What Point the Sun is in, is known by the Mariner's Compaſs.

PROPOSITION V.

To know by the Globe, (when the Sun ſhines) the Hour in a place whoſe Latitude is given.

ELEVATE the Globe for the Latitude, and make it's Axis point to the North; then fix a Needle perpendicular in the Sun's Place under the Meridian,

Meridian, the Hand being at 12; turn the Globe till the Needle be under the Sun, and makes no Shadow on the Globe; and the Index will show the Hour.

PROPOSITION VI.

Having the Hour, as we reckon it, to know the Hour from Sun-rising, i. e. *the* Babylonish *Hour, or the Hour at* Norimberg.

THE *Babylonians* of old, and the People of *Norimberg* now, count twenty four Hours, from Sun-rising to Sun-rising the next Day. Elevate the Pole for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe till the Index point to the Hour given, then the Globe being fixed, bring the Index back to it, then turn it from West to East till it come to the Horizon, and count the Hours from it to the Index Eastward; and these are the Hours sought.

PROPOSITION VII.

Again, having the Babylonish *Hour, to find the Hour by our Reckoning,* i. e. *from twelve at Day, or Night.*

ELEVATE the Pole for the Latitude, and bring the Sun's Place to the Horizon on the East, and the Index to it, and turn the Globe till the Index points to the Hour from Sun-rising; then bring the Index back to 12, and turn the Globe till you bring the Sun's Place under the Meridian, and you'll see how many Hours 'tis past 12 or before 12, by your reckoning.

PROPOSITION VIII.

Having the Hour, as we reckon it, to find how many Hours are past since the Sun set last; that is, the Italian *Hour.*

THEY now in many places of *Italy*, as of old in *Greece*, begin their Day at Sun-set; which lasts till the next Sun-setting.

TO find their Hour; elevate the Globe for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe till it point to the Hour given, then bring the Hand to 12, and turn the Globe to the East till the Sun's Place come to the Horizon, and count the Hours from 12 to the Index.

PROPOSITION IX.

Having the Italian *Hour from Sun-setting, to find the Hour, as we reckon it, from Mid-day or Midnight.*

ELEVATE the Globe for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe Westward till the Index point to the Hour given, then the Globe being fixed, bring back the Idex to 12, then turn the Globe till the Sun's Place come under the Meridian, and count the Hours from 12 to the Index Eastward; and you have the Hours from Midday or Night, according to our reckoning.

PROPOSITION X.

Having the Hour, as we reckon it, in a given Day, to find the Jewish *Hour, as they and others reckoned.*

IT

IT appears from the Diſcourſe of *Chriſt*, about the hiring of Labourers to the Vineyard, that the *Jews*, and other Nations before Aſtronomy was cultivated, divided the Day, from Sun-riſing to Sun-ſetting, into twelve Hours, and the Night into as many, which are called Planetary Hours for another Reaſon; but they are rather to be called unequal Hours: for ſeeing neither Days nor Nights are equal, but increaſe the one half of the Year, and decreaſe the other, except under the Equator; the Hours muſt be ſometimes longer, and ſometimes ſhorter; tho' near the Equator there is no great Alteration, as we ſhewed *Chap.* xxv. and therefore they that are far from the Equator, as the *Europeans*, never uſed that Way, but only they in the *Torrid Zone*, or not far from it.

THE Problem then may be propoſed more clearly thus: *Having the equal Hour in any Day, to find the unequal Hour, which is the twelfth part of the Time* the Sun is above the Horizon; but the equal Hour is the twenty fourth part of the Time the Sun takes in going from the Meridian till it returns to it; which is the Aſtronomical Day.

TO ſolve the Problem: Elevate the Globe for the Latitude, bring the Sun's Place to the Eaſt Horizon, and the Index to 12, and turn the Globe 'till the Sun's Place come to the Weſt: Thus you find the Length of that Day. Then find the Hour from Sun-riſing or Sun-ſetting, if the Hour given be after Sun-ſetting, by *Prop.* vi. and viii. and ſay, as the Length of the Day (or Night) in Hours is to twelve Hours; ſo are the Hours from Eaſt (or Weſt) to the *Jewiſh* Hour.

PROPOSITION XI.

Having the Jewish *Hour in a given Day, to find the Hour with us; or to reduce the unequal Hour to the equal.*

DO as in the last Proposition, and find the equal Hours in the Day; and when the Sun riseth; then say, as twelve is to the *Jewish* Hour given, so is the Length of the Day to a fourth Number; which add to the Hour of Sun-rising, and you'll have the Hour from Mid-night if the Number of these Hours be above twelve; reject twelve, and you have the Hour from Mid-day.

THE *Jewish* Hours, mentioned in *Christ*'s Discourse, cannot be accurately reduced to our Hours, the Day of the Year not being added; therefore that third Hour may be our ninth, tenth, or eighth, and the eleventh Hour may be our fifth, sixth, or seventh, according as the Day was in Summer, Winter, or in the Equinox; but the heat of the Day being mentioned, 'tis likely it was about the Summer Solstice.

PROPOSITION XII.

They who sail to the East, till they come back to the place they left, have seen the Sun rise, pass the Meridian, and set once more than the People they first left; and thus are one Day before them; the first of January *is the second to them, and our* Saturday *they count* Sunday; *and if they sail round twice or thrice, they will count two or three Days more.*

And

And they who ſail to the Weſt, round the Globe, count one Day leſs, ſo that 'tis the thirty firſt of December *with them, when it is the firſt of* January *with others; and our* Sunday, *they count* Saturday; *and they loſe as many Days as they ſail Times round that way.*

THIS was formerly a great Wonder to Seamen and others: after they had ſailed Weſt and came to the *Oriental Iſlands*, and found they differed from other *Europeans* there by a Day, they accuſed one another of Negligence or Sleepineſs; but the frequency of the Thing hath now taken away the Wonder, and given Mathematicians occaſion to explain the Cauſe of it; which is very plain, if Men will but conceive aright the Motion of the Sun, or of the Meridians on the Earth, and fix on ſome Beginning of the Day; for it depends on the diurnal Circumvolution of the Sun, (not on it's proper Motion, as ſome thought) which may begin at any Meridian Circle, and from thence go round till it come back to the ſame Meridian.

AND becauſe they that ſail Eaſtward go to a Meridian to which the Sun comes ſooner than to that they left, they therefore begin to count another Day ſooner, For Example; if they ſail fifteen Degrees Eaſtward, they will begin the Day an Hour ſooner, and this Anticipation ſtill increaſes as they go Eaſtward; and being come to the oppoſite Meridian, their Day begins twelve Hours ſooner; and having gone round, they begin the Day twenty four Hours ſooner than in the Place they came to, where it is Mid-day to both when the Sun is in the South.

AND ſo they that go Weſt will have the Sun later in their Meridian by a whole Hour, if they ſail fifteen Degrees to the Weſt, which poſtpones

the Day ſtill an Hour for every fifteen Degrees, which comes to twenty four Hours in ſailing round.

COROLLARY I.

IF one ſail Eaſtward and another Weſtward, both round till they meet, the firſt will count two Days more than the ſecond; and if they ſail twice round he will count four Days more, tho' they live the ſame Number of Days; and the Days of the Eaſt Traveller will be ſhorter than the Days of the other.

COROLLARY II.

THE ſame would happen in whatever Place they ſhould meet one another, and from this was the Fact found firſt, and often afterwards; for when *Ferdinand Magellan* had paſſed the Straits of *Magellan* and come to *India*, he found a Day's difference in his Account, from the Account the *Europeans* had there, who ſailed to the Eaſt; and ſo it was with all others that ſailed round.

COROLLARY III.

HENCE it is that they differ in a Day in ſome Places near one another in the ſame Meridian, as in the *Philippine Iſlands*, and *Macao*, a Sea-port in *China*, poſſeſſed by the *Portugueſe*. and the *Iſles* by the *Spaniards* of *Caſtile*, as they ſay; for they are under the ſame Meridian, yet in *Macao* it is *Sunday*, when in the *Philippines* it is but *Saturday*; and while in *Macao* they have *Eaſter*, and eat Fleſh, in the *Philippines* it is but *Lent*; and they celebrate not the Feaſt till the

 morrow:

morrow: the Reaſon is, the *Portugueſe* came Eaſt to *India*, and from thence to *Macao*; whereas the *Spaniard* ſailed Weſt and came from *America* Weſtward to the *Philippines*; and tho' they met in two Meridians near the ſame, yet they differ one Day in their reckoning.

CHAP.

CHAP. XXX.

Of the different rising and setting of the Sun, with it's Altitude, and other Appearances, in different Parts of the Earth.

PROPOSITION I.

To place the Globe, so that the Sun shining on it, those Parts may be illuminated which the Sun illuminates any Day; and that it may at the same Time appear to what People the Sun riseth every Minute, and to whom it is Mid-day; to whom it sets, and to whom it is Night, and to whom it is vertical; as likewise the Sun's place in the Ecliptic, the Day of the Year, and the Hour of the Day in that place.

LET the Place, for which the Globe is to be so situated, be mark'd on the Globe, and brought to the Meridian, and the Point on the Meridian above it be marked with Chalk, and on that Point hang the Globe; and if you would have it fast, you must run an Iron Rod thro' that Point, and the Center to the opposite Point, and have the same well fixed to some Plain below.

THEN place the Globe due North and South by a Meridian Line, or by the Compass: the Globe being thus placed, you may see every Minute the enlightened Part of the Earth, and that which is dark, and the Places in the middle of the illuminated Part have Mid-day then, and those in the eastern

eastern Meridian that bounds the Light and Darkness have the Sun setting, and those in the western the Sun rising.

TO find the Sun's Place in the Ecliptic: Move a small Needle, placed perpendicularly about the middle of the enlightened Part till it have no Shadow, and that Place on the Globe brought to the Meridian, will show the Declination of that Point of the Ecliptic in which the Sun then is; and the Sun's Place will be known according as the time of the Year is, and from thence the Day of the Year; and that Place where the Needle hath no Shadow, hath the Sun vertical to it, and a Parallel thro' that Place will show all the Places that will have it vertical that Day. And to find the Hour of that Place for which the Sun is thus fixed, bring the Place to the Meridian, and the Index to 12, and turn the Globe till the Place, or that for which the Globe is situated, come to the Meridian, and the Index will show the Hour.

BUT because the Globe cannot revolve while it is fixed to the Iron Rod, it will be convenient to fix a Quadrant on a Meridian, so as to turn round the Pole, or an Arc of 113½ Degrees, which being brought to the Needle's Place, will show the declination of the Sun; from which may be found the Sun's Place and Day of the Year: and the Difference between that Arc and the Brass Meridian counted on the Equator, will give the Degrees; which being turned to Hours, fifteen Degrees to an Hour, will give the Hour of the Day before or after twelve, as the Sun is to the East or West Side of the Meridian.

IF there be fixed to the Pole of the Globe such an Arc of Brass as was before said, there may be fixed to it a piece of Brass that hath a perpendicular Style on it, which piece shall slide up and down, according to the Sun's Distance from the Equator: thus there

there will be no need of a Needle, or ſpherical Gnomon, and it will be leſs liable to Error.

PROPOSITION II.

The Globe being placed as before, it may be ſhewn (when the Moon ſhines) to what People the Moon appears any time it is above our Horizon; and who have the Moon riſing, ſetting, or in their Meridian.

THESE are all plain from the preceding Propoſition.

PROPOSITION III.

The further any place is from the Parallel the Sun is in at any Time, the Sun riſes the leſs above their Horizon.

TAKE any Place in the ſame Meridian where they reckon the ſame Hours, then deſcribe the Sun's Parallel for any Day, and it will appear that any Point in it will be further diſtance from that Place which is furtheſt from the Parallel, (and the ſame way it is in the Heavens) and ſo the Altitude will be leſs.

PROPOSITION IV.

The nearer a place is to the Pole, the Points on the Horizon in which the Sun riſes or ſets at the Summer and Winter Solſtice, are the more remote; and the ſame may be ſaid of the Moon and other Planets.

TAKE two Places of different Diſtances, and elevate the Pole for their Latitude, and you'll ſee where the firſt of *Cancer* riſes, and the firſt of *Capricorn*, at both theſe Elevations, for which you ſee

see that they are more distant in the greatest Latitude or Elevation; and their Distance from the East in rising, or West at setting, which Astronomers call the *Amplitude*, is greatest in the greatest Latitude.

PROPOSITION V.

The Stars situated between the Parallel of a place not in the Equator, and the Pole, are less elevated above the Horizon of the places between that Parallel and the other Pole, than in the places between the Parallel and the nearest Pole.

THIS is easily tried by elevating the Globe for two Places.

PROPOSITION VI.

In places in the Equator the Sun and Stars rise directly up to the Meridian; but in places out of it obliquely.

DRAW a Parallel of the Sun on the Globe, and place the Poles in the Horizon, and you will see any Point in the Parallel rises directly above the Horizon; and elevate the Globe for some other Latitudes, and you will see the Parallel become more oblique to the Horizon, and most at the greatest Latitude.

PROPOSITION VII.

The greater the Latitude of a place is, a Sign in the Ecliptic takes the more time in rising; but they all pass the Meridian in equal times.

ELEVATE the Globe first for one Latitude, and bring the beginning of the Sign to the Horizon,

rizon, and the Index to 12, and you will ſee how many Hours paſs before the Sign be wholly above the Horizon: and do ſo for a greater Latitude, and the Propoſition will be plain.

PROPOSITION VIII.

The Day being given, to find where the Sun will riſe in any given Point.

THIS Problem ſhould be propoſed of the Earth itſelf, as alſo thoſe that follow, if we were treating ſcientifically; for it is a Property of the Earth and not of the Globe; yet the Globe repreſenting the Earth, it is ſufficient for Practice.

THE Problem is the ſame with that *Prop.* xi. *Chap.* xxiii. where having the Point and the Day of the Year in which the Sun riſeth, to find the Latitude of the Place, or the Parallel in which we may be ſure we are.

PROPOSITION IX.

The Day and Hour, or Part of an Hour, being given, to find the Point on the Globe, to which the Sun is then vertical.

BRING the Sun's Place to the Meridian, and mark the Point above it; then find thoſe Places in whoſe Meridian the Sun is at that Time, and bring them to the braſs Meridian; then the Place under the marked Point is the Place ſought.

PROPOSITION X.

The Day and Hour being given, to find thoſe places where the Sun hath a given Altitude under ninety Degrees.

FIND

FIND the Place the Sun is then vertical to, and bring it to the Meridian, and fix the Quadrant of Altitude in the Point above it, and mark the given Altitude on the Quadrant; then turning it about, the Mark will go over all the Places where the Sun hath that Altitude above the Horizon.

PROPOSITION XI.

To find all the Places on the Globe where the Sun is rising, setting, and in the Meridian; and what Places are enlightened, or in the dark, at any Hour of the Day given.

FIND the Place where the Sun is then vertical, and bring it to the Meridian, and elevate the Globe for the Place, then all the Places under the Brass Meridian have Mid-day; and those in the West Horizon have the Sun rising; and those in the East Horizon have it setting; and the Places above the Horizon are enlightened; and those under are in darkness.

NOTE. This is to be understood of the Center of the Sun's rising and setting; for the Sun illuminates something more than the Half of the Earth; as we shall see in the following Proposition.

COROLLARY.

WE may thus see where the Sun rises or sets at our Mid-day, or where 'tis Mid-day when 'tis Night in our Horizon; which is a pleasant Diversion.

PROPOSITION XII.

Having the Semidiameter of the Sun, and of the Earth, and the Distance of the one from the other, to find how much of the Earth is illuminated by the Sun.

(*Fig.* 33.) LET the little Circle be the Earth, A it's Center, and S the Sun's Center, LB and *oc* will be the Rays that touch the Globe of the Sun and Earth, and distinguish the enlightened from the dark Part, *i. e.* BD*c* from BE*c*. Let the two Rays LB, *oc* meet in R, and BN be drawn parallel to AS. In the Triangle BNL there is given NL, the excess of SL above AB, and BN equal to AS; and BLN is a right Angle, BL being a Tangent; then find the Angle NBL, As BN is to NL, so is the whole Sine to the Sine of the Angle BNL; and LNB and NBL being equal to a right Angle, and BNL equal to ASL or BAR.

THEREFORE the Arc of the Angle NBL is equal to the Arc BM, the excess of DB above ninety Degrees, and so the Arc DC.

AND if we make the Sun's Semidiameter $5\frac{1}{2}$ of the Earth's, and AS 1168 Semidiameters, MB will be thirteen Months more than the half MEQ.

COROLLARY.

WHEN therefore the Center of the Sun rises to a Place, it's Limb rises to the Inhabitants in a Parallel to the Horizon thirteen Minutes under it; and when the Sun's Center sets, it's Limb is seen 'till it's Center set to those in a Parallel thirteen Minutes from our Horizon.

PRO-

PROPOSITION XIII.

Having the Height of a Mountain, to find how much sooner the Sun will rise, and how much later it will set, than in the Valley below.

FROM the given Height find, by *Prop.* v. *Chap.* ix. the Interval, or Arc, from which the Top of the Mountain may be seen; or where the Tangent Line will terminate the Arc: this Tangent Ray is the first that can come from the Sun to the Top of the Mountain.

THIS Point in which the Ray, from the Top touches the Earth, is the Place where the Sun rises when 'tis first seen at the Top; and this Arc shows how much the Sun is under the Horizon of the Valley, when first seen at the Top.

THE Problem then comes to this; having the Depression of the Sun under the Horizon, to find how soon it will come to the Horizon: from which it appears, that it will depend on the Time of the Year. Let the Pole then be raised for the Latitude of the Place, and the Quadrant fixed to the Zenith; then bring the Point opposite to that in which the Sun is at a given time to the western Horizon, and the Index to 12, then observe the Degrees of Depression under the Horizon on the Quadrant, and make that Point come as high above the Horizon, by applying it to the Quadrant, and the Sun will then be so far under the Horizon; then turn the Globe 'till it come to it, and the Index will show the Time. But because the Time is small, 'tis better to do it by Calculation. Supposing then the Height of the Mountain three Quarters of a *German* Mile, and the Depression about three Degrees, the Latitude of the Place thirty eight Degrees, and the

Sun in the fifteenth of *Leo*, and that the Sun is ſeen at the Top thirteen Minutes ſooner than below. Hence it will appear how unlikely it is that *Ariſtotle* ſays of the Tops of *Caucaſus*, and *Pliny* of the Mountain *Caſius*, *viz.* that they are enlightened a third Part of the Night. But how high that ſuppoſes the Mountains to be we ſhall ſhow in the following Propoſition.

PROPOSITION XIV.

Having the Time that the Sun is ſooner ſeen on the Top than at the Foot of a Mountain, to find it's Height.

ELEVATE the Globe for the Latitude of the Foot of the Mountain ; mark the Point on the Ecliptic oppoſite to the Sun's Place, and find how much the Sun is depreſſed for that Time ; then from that Arc, as a Diſtance from which the Top can be ſeen, find the Height by *Prop.* iv. *Chap.* ix.

PROPOSITION XV.

Having the Moon's Place in the Zodiac, and it's Latitude, to find the Places it will be vertical to in it's Revolution that Day.

MARK the Moon's Place, taken from an Ephemeris, on the Ecliptic, and apply one end of the Quadrant of Altitude to the Pole of the Ecliptic; and the other to the Mark in the Ecliptic ; obſerve the Moon's Latitude on it, and mark the Moon's Place thus on the Globe with Chalk, deſcribe a Parallel thro' it, and all the Places in the Parallel give the Anſwer. Underſtand the ſame as to the other Planets ; having their Latitude and Longitude given.

PRO-

PROPOSITION XVI.

Having the Moon's Place in the Zodiac, with it's Latitude and Day of the Year, to find when it will rise, set, or be in the Meridian in any Place.

ELEVATE the Globe for the Latitude, and mark the Sun's Place, and also the Moon's, as we shewed in the preceding Proposition; then bring the Sun's Place to the Meridian, and the Index to 12, and turn the Globe 'till the Moon rise, be in the Meridian, and set; and the Index will show the Hour. The same may be done for the other Planets.

PROPOSITION XVII.

To find the Places on the Globe where the Moon will be, rising or setting, or in the Meridian, at any Hour, having it's Latitude and Longitude.

MARK on the Globe the Sun and Moon's Place as before, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe 'till the Moon's Place come to the Meridian; and mark the Hour on the horary Circle; for thereby you know in what time the Moon will come to the Meridian after the Sun; and then describe the Parallel of the Moon, by bringing it to the brass Meridian. Next bring the Sun's Place to the Meridian, and the Index to 12, and turn the Globe 'till it point to the Hour given; and all the Places under the Brass Meridian will have the Moon then in their Meridian. Bring back the Index to 12, and turn the Globe 'till it point to the Hour given; then the Point in the Parallel under the Brass Meridian, shews the Place where

'tis then vertical: which Place bring to the Zenith of the Horizon; and those in the East Horizon have the Moon setting, and in the West, rising. The same may be done for the other Planets.

PROPOSITION XVIII.

Having the Day and Hour in which there is to be an Eclipse of the Moon; to shew on the Globe all the Places where it can be seen, and particularly those that will have the Moon in their Meridian, and in their Horizon, either rising or setting.

THIS differs a little from the former; but hath a much easier Solution.

FROM the given Day mark the Sun's Place, and the Point opposite to it is the Moon's Place.

FIND the Place on the Globe where the Sun is then vertical, and find their *Antipodes* by *Prop.* vi. *Chap.* xxviii. and with them the eclipsed Moon will be vertical. Elevate the Pole for the Latitude of that Place, and bring it to the Zenith, and all the Inhabitants above the Horizon will see the Eclipse; and they under the brass Meridian will see it in the Meridian; and those in the West or East Horizon will see it rising or setting.

BUT whereas an Eclipse lasts some Hours, and there may be considered it's beginning, middle, and end, we here consider only it's middle.

AND the Moon being less than the Earth, it illuminates less than an Hemisphere; and is seen at once by the Inhabitants in the lesser Part, so as 'tis not longer seen by those in the eastern Horizon, tho' at the same Time it hath not yet appeared to those in the western Horizon. And we must conceive a small Circle parallel to the Horizon that terminates the light and dark Part: and

how much 'tis leſs than the Hemiſphere we ſhall ſhow in the next Propoſition.

PROPOSITION XIX.

Having the Semidiameter of the Earth and Moon, and their Diſtance; to find how much of the Earth may be illuminated by the Moon at once.

THIS is done the ſame way as in *Prop.* xi. Let (*Fig.* 33.) the Center of the Earth be S, and of the Moon A, draw the Tangents LB, OC; theſe are the laſt Rays that come on the Earth, and ſo the Arc OHL denotes the Part that is illuminated, where they can all ſee the Moon at once, which how much leſs it is than an Hemiſphere, will appear by finding the Angle HSL, or the Arc HL. Draw BN parallel to AS, then BA will be equal to SN, and NL the Difference of the two Semidiameters, and BN being equal to AS, and NLB is a right Angle. Then in the Triangle NBL the Angle NBL may be found thus; As NB to NL, ſo is the whole Sine to the Sine of the Angle LBN, whoſe Arc is the Difference of HL and a Quadrant. Suppoſe then the Diameter of the Moon, to be $\frac{4}{15}$ of the Earth's; and in full Moon, let the Moon's Diſtance be 64 Semidiameters of the Earth, then NL will be $\frac{11}{15}$; and As 64 is to $\frac{11}{15}$, ſo is 10000000 to 114583 the Sine of 39 Minutes, and ſo HL is leſs than 90 Degrees by 39 Minutes or 89 Degr. 21 Min.

A Place therefore being fixed on the top of the Horizon, the People, to whom the Moon riſes and ſets, will not be thoſe who are viſible in the Horizon itſelf, but in a Parallel of the Horizon, 39 Minutes diſtant from it.

PROPOSITION XX.

Having the Declination of a Star, to ſhow on the Globe all the Places where that Star will be vertical in it's Revolution.

MARK it's Declination on the braſs Meridian, and under that Mark draw a Parallel, and you have the Places.

PROPOSITION XXI.

Having the right Aſcenſion of a Star, and the Day of the Year, and Hour of the Day; to find the Places where that Star will be in the Meridian at a given Hour.

MARK the right Aſcenſion of the Star on the Equator, and bring the Sun's Place to the Meridian, and ſee what Degree of the Equator is in the Meridian; then the Diſtance of the two Points obſerved being turned to Time, ſhows the Difference of the Times of the Sun and Stars coming to the Meridian; then find the Places where the Sun is in the Meridian at the given Hour, and the Hand being brought to 12, turn the Globe 'till the Degrees marked on the Equator come to the Meridian; then all the Places under the braſs Meridian will have the Star in their Meridian at that Time.

PROPOSITION XXII.

Having the Declination and right Aſcenſion of a Star, and the Time of the Day given, to find by the Globe, (1) *The Place 'tis vertical to.* (2) *The Places where 'tis above, and where 'tis under the Horizon; and* (3) *where 'tis in the Meridian, and where it then riſes or ſets.*

FIRST

FIRST, from it's right Aſcenſion, find where the Star is then in the Meridian, and keep thoſe Places under the Meridian, and count the Declination of the Star on the Braſs Meridian, and you have the Place it is then vertical to; bring that Place to the Zenith, the Globe being elevated for it's Latitude, and thoſe Places under the braſs Meridian will have the Star in the South or North Meridian, and thoſe in the Eaſtern Horizon will have it ſetting, and in the weſtern riſing.

PROPOSITION XXIII.

To find by the Globe the Places where the Sun, Moon, and Stars will be as long under the Horizon as they are above, with us or any others.

BRING the Place to the Meridian, and find the Antœci of that Place; who will have them as long under the Horizon, as they are above in that Place; as may be eaſily ſhewn on the Globe.

PROPOSITION XXIV.

To ſhow the Cauſe why the Length of the Days increaſes or decreaſes faſter at the Equinoctial than at the Solſtices, when there ſeems to be no difference; and that in all Places, except under the Equator; and the more the further from the Equator.

FOR Example; Let us take thirty Days before the vernal Equinox (from the twenty firſt of *February* to the twenty firſt of *March*), and thirty Days after the Winter Solſtice (from the twenty firſt of *December* to the twenty firſt of *January*): I would know why the twenty firſt of *March* exceeds the twentieth of *February*, more than the twenty

twenty first of *January* doth the twenty first of *December*.

THE Parallel for these four Days being drawn, you will see that of the Equator is further from that in the first of *Pisces* or *Scorpio*, than that thro' *Aquarius* or *Sagittarius*, is from that thro' the first of *Capricorn*; whence there is not much more of the Parallel thro' the first of *Aquarius* above the Horizon, than of that thro' the first of *Capricorn*; but much more of the Parallel, thro' the first of *Aries*, or of the Equator, is above the Horizon, than of the Parallel thro' the first of *Pisces*. Whence we understand that the Length of that Day is owing to the Declination of the Sun, or of the Points of the Ecliptic. Under the Equator the Days are still equal, tho' the Sun seems at the Solstice to stand or change but a little the meridian Altitude; and it will appear that the inequality of the Days is the more sensible, the further the Place is from the Equator; if you elevate the Globe for those Places, you will see a greater Difference in the Arches of the Parallels above the Horizon.

PROPOSITION XXV.

In Places at the Equator the Sun goes faster from the Zenith than in Places near the Tropics, and within the Torrid Zone.

MARK on the brass Meridian, suppose the fifth Degree of Latitude, and another in eighteen Degrees brought to, and marked on the Meridian; and count five Degrees from it towards the Tropics on the brass Meridian, and set a mark there also; it may be shown that the Sun will sooner increase in the five Degrees of Declination near the Equator, than in those from it: for turning the Globe

Globe 'till a Point in the Ecliptic comes under eighteen Degrees, and 'till again it comes under thirteen, which is five leſs, it will cut off a greater Part of the Ecliptic than is between the two Points that come under the fifth Degree, and the beginning of the firſt; and therefore the Sun goes ſlower from the Zenith in the ſecond Place, than from the Zenith of the Place in the Equator.

THE

COMPARATIVE PART OF Univerſal Geography.

BOOK III.

Of the Properties ariſing upon comparing one Place with another.

CHAP. XXXI.

Of the LONGITUDE.

DEFINITIONS.

THE Circle of Longitude of any Place is the Circle that paſſes through the Place, and both the Poles. It is alſo called a Meridian Circle, which are one and the ſame Thing; tho' different in ſome Reſpects: for the Meridian hath reſpect to the Motion of the Stars, and the Circle of Longitude to the Earth's Extenſion, without regard to the celeſtial Motions. But the Meridian is

is the more common Name, which we ſhall therefore uſe here. They are plainly ſeen on the Globes, and in the Maps, paſſing thro' every ten Degrees of the Equator.

2. THE Longitude of a Place is the Diſtance of it's Meridian, from a certain Meridian (meaſured on the Equator) which is called the firſt; and the Longitude of the Earth itſelf is it's Extenſion from Weſt to Eaſt, conceived on the Equator. The firſt Meridian is made conſpicuous on the Globe and in Maps.

3. THE Diſtance of one Place from another is the ſhorteſt Line between them, on the Earth's Superficies.

4. ANY Point on the Globe, or Map, is ſaid truly to repreſent ſome Place on the Earth, if it hath the ſame Situation and Diſtance to the other Points on the Maps, that the Place hath to the other Places repreſented by them.

PROPOSITION I.

There is no Meridian determinated in Nature to be the firſt, and therefore any one may be taken for the firſt.

TO underſtand this aright we muſt go a little back; for ſome conceive a Myſtery here, where there is none. All Superficies both plain and curve are meaſured by two Dimenſions (as a Line is by one, and a Body by three) as is known from Geometry, and the common Buſineſs of Life; of which two, one is Length, and the other Breadth; and the one is conceived perpendicular to the other: and theſe two are not in themſelves different; for that we call Length may be called Breadth, tho' the longeſt is uſually called Length.

IN regular Figures, as equilateral Triangles, Squares, &c. these two Dimensions are the same, but the Earth's Superficies is spherical, and the Length not really different from the Breadth, except in our Conception, for the more distinct understanding of the Thing. And these two Extensions may be conceived on the Earth thus; if we take the Periphery of a Semicircle from one Point to it's opposite Point, it will be one Dimension; and if that again be cut in the middle at right Angles by a Circle (as the Length and Breadth is taken in all Superficies) that shall go round, and be the other Dimension for measuring the Earth's Superficies, as if it were extended into a Plane. The first of these being only a Semicircle may be called the Latitude of the Globe; the other being a whole Circle the Longitude of it. Some say they are called Latitude and Longitude because a less Part of the Earth was known to the Antients towards the Poles than eastward or westward.

MOREOVER, on the Globe any Semicircles between the Poles may be taken for the Latitude, and a Circle perpendicular to it, for the Longitude, and so on the Earth; but for the memory sake, it is best to take such Lines as have something peculiar and remarkable, as the Line from Pole to Pole, and the Circle that passes in the middle between them, as the Equator doth.

THUS it appears plain, why the Latitude is measured on the Meridian, and the Longitude on the Equator.

THIS Latitude and Longitude of the Earth is not to be taken for those of a particular Place: for they are only expressed so because they are measured on those of the Earth, and are a Part of them.

AND, properly speaking, a Place or Point, hath neither Latitude nor Longitude: and these two different Senses of the Words ought to be well remembred;

membred; for the Words frequently occur among Geographical Writers; as when we speak of the Latitude and Longitude of *Spain*, the Words are taken properly for Length and Breadth; but when we speak of the Latitude and Longitude of a Place, taken as a Point we mean it's Distance from the Equator, and from the first Meridian; and in my Judgment it were better not to use the Words Latitude and Longitude, but only Distance from the Equator, and from the first Meridian: but being so long used they cannot be now abolished; and we shall use them hereafter in this Sense.

MOREOVER, the Latitude of a Place hath, like the Latitude of the whole Earth, remarkable Places for the beginning of the reckoning; as the Poles and the Equator; but the Longitude going round the Earth, hath no certain Place, for a beginning: and therefore we may begin at any Point in the Equator, and count the Meridian that passes thro' it the first Meridian, from which the rest are reckoned.

WE shall show why these two Distances from the Equator, and the first Meridian are enquired after, as in *Prop.* iii.

PROPOSITION II.

To determine the first Meridian on the Globe of the Earth, from which we are to begin to reckon the Longitude.

WE said before that we may begin at any Point on the Equator to reckon the Longitude, but 'tis better to fix upon one place, thro' which a Meridian being drawn, may be counted the first. Geographers have not all agreed on this Place. *Ptolemy* chose to make that the first Meridian which passes near

near the *Fortunate*, which are Islands about one Degree from it; and reckons from thence to the East thro' *Africa* and *Asia*; chusing to begin at a Place inhabited, and which was then the Bounds and Limits of the known Part of the Earth to the West, and to end at the eastern Shore of *Siam* in *Asia*; but *America* being known not many Ages ago, and long after *Ptolemy*'s Time, the first Meridian was removed more to the West. Some made that the first which passes thro' the Isle of *St Nicolas*; which is one of those near Cape *Verd*; and *Hondius* chose the Isle of *St James* to be the first Meridian in his Maps.

OTHERS chose that which passes thro' the Isle *del Corvo* one of the *Azores*, because the Needle was found not to decline from the North there, and in the adjacent Seas, but to lie in the meridian Line; and this beginning *Mercator* chuses.

BUT seeing there are other Places where the Needle points to the North, and it doth not so in every Part of that Meridian; Geographers thought this not a sufficient Reason; some fixing it at the Shore of *Brasil*, that runs out into the Sea.

LATER Geographers, especially the *Dutch* chuse to begin at the Mountain *Teneriff*, in the *Fortunate*, or *Canary*, Isles, which is counted the highest on Earth, and is called the Pike of *Teneriff*; and the rather because they thought some remarkable Place should be chosen that might be most known to future Ages; and so *Ptolemy*'s first Meridian, tho' long observed, was not laid aside without good Reasons. The *French*, since the Year 1634, have taken that which goes thro' the west Part of the Isle of *Ferro*, one of the *Canaries*, which the *French* King, *Lewis* the thirteenth, commanded his Sailors and Geographers to observe.

ASTRONOMERS also have taken diverse Places for the first Meridian; the Followers of *Tycho*

Tycho fix it at *Uranoburg*, an Island in the *Danish* Streights, and calculate the celestial Motions to that Place, and from thence accommodate them to the rest. Others chuse other Places according to the Authors of the Ephemeris they use, who calculate the Ephemeris, and the Planets Places for the Meridian of their own Place. As *Origanus* for *Frankfort*; *Maginus* for *Venice*; *Eickstadius* for *Stetin*; *Lansberg* in his Table takes *Gœsa* in *Zeeland*, and *Reinholdus* the Royal Mountain of *Prussia*.

BUT to say the Truth, all this Difference hath arisen without any Foundation; so that they are to be blamed who first changed *Ptolemy*'s Meridian: for it is no matter where they begin, whether at a Place remarkable, or most to the West or East, provided we may know the Situation and Distance of other Places from it accurately; and that variety of first Meridians hath burthened the reading of Geographical Writers with Confusion and Difficulty. Yet because the Knowledge of the Variation of the Needle from the Meridian is of great Advantage, and that Variation increases to a certain Meridian, and then decreaseth; it will be useful for finding that Variation, and comparing the Increase and Decrease of it, to chuse that for the first Meridian, in which, or in most Places of it, the Needle hath little or no Variation; if any such is to be found.

AND seeing the *Dutch* now use that which goes over *Teneriff*, and they sail to all Parts of the Earth; it will be convenient to use that with them, for the better understanding the Diaries they publish.

AND Students should know in reading of Authors, that where mention is made of the Longi-

tude of a Place, or of a certain Meridian, where the Author begins his firſt Meridian.

PROPOSITION III.

Having the Latitude and Longitude of a Place, to find it on the Globe or Map; and ſo it's Situation and Diſtance from other Places.

THE Problem for which a Method is ſought with ſo much Care and Induſtry, is, to find the Longitude of the Place in which we are; and before I come to it, I thought fit to premiſe the Problem for which the Longitude is wanted; leſt the Reader ſhould be diſguſted for want of knowing the uſe whereto it is ſubſervient.

FOR Seamen (as to thoſe that travel by Land they have not much need of it) having gone far from Land, and not being ſure of the Way they went, becauſe of ſeveral Difficulties, they cannot trace it out certainly in the Maps, and ſo cannot determine the Ship's Place, or the Courſe they muſt ſteer to their deſired Port; which they could do if they had both their Latitude and Longitude. Mathematicians have taught them to find the Latitude at Night by the Stars, and in the Day by the Sun; as we have ſhewn before: they that pretend to do it by the Magnetic Needle, ſhow their want of Skill. And if they had the Longitude, then where the Meridian they are in cuts the Parallel of their Latitude is the Place they are in, on the Globe or Map. And this Method of the Section of two Lines is uſed frequently to find a Point's Place.

FOR the Solution of the third Problem, count the Degrees of Latitude from the Equator on the braſs Meridian, and having chalked it, draw the Parallel; then bring the known Meridian the Place

is in (which is distant from the first by the Degrees of Longitude) under the brass Meridian, and where it cuts the Parallel of Latitude is the Place sought: if any Meridian be drawn thro' the Place, the Work is easier.

IN strait lined Maps (such as the Seamens are) find the Latitude on the Margins on both Sides, and draw a Line thro' them which represents an Arc of the Parallels; then at the Head and Top find the Longitude, and draw a Meridian thro' the Degree of Longitude, the point of Intersection is the place. Or shorter thus; Lay a Ruler on the Degrees of Longitude, at the Head and Bottom, and set the Degree of Latitude taken from the Map with a Pair of Compasses along the Side of the Ruler, and you have the point. And the same Way in curve lined Maps; only we must draw circular Parallels.

THIS is the first remarkable Use of the Longitude in sailing.

THE second use is more necessary; *viz.* the Construction of Globes and Maps thereby; for the places are by the Latitude and Longitude set down on Globes and Maps: and hence it is they are often made so as not to represent the Situation of the place truly, for want of the true Longitude.

THE third use is also famous; *viz.* the knowing the Hour in other places when any celestial Appearance happens; of which in the following Proposition.

THE fourth use is to find the Distance of two places; having their Latitude and Longitude given.

PROPOSITION IV.

The Sun, Stars, and every Point of the Equator or Parallel, removes from the Meridian 'tis in, fifteen Degrees in an Hour, or in a Minute of Time, fifteen Minutes of a Degree; and in four Minutes one Degree.

FOR an Hour is but the twenty fourth Part of time in which they revolve from any Meridian 'till they return to it; and three hundred and sixty Degrees in the Circle divided by twenty four gives fifteen in the Quotient.

THE same will appear on the Globe: bring a Point on the Equator to the Meridian, and the Index to 12, turn the Globe 'till the Index Point to 1 or 2, and you will see fifteen Degrees have passed thro' by the meridian.

COROLLARY.

IF a Place be fifteen Degrees more easterly than another, it will be eight or nine o'Clock with them by an Hour sooner than in the other Place; if thirty Degrees, two Hours sooner; and so they will have the heavenly Appearances so much sooner than the other: but if more westerly than the other, they will be so long behind the other in their reckoning: or, which is the same thing, if one hath an Appearance in the Heavens, as an Eclipse, an Hour sooner than the other, they will be fifteen Degrees more easterly.

Note. When we add the Sun and Planets with the fixed Stars; as in saying they move fifteen Degrees westerly each Hour; we do not understand it to be exactly so, for tho' it is true of the Stars, yet because the Sun and Planets in the man time

revolve to the East, they come later to the meridian, and by degrees they remove from the fixed Stars; but it is so little in a Day, (being in the Sun but ten Seconds, and in the superior Planets less), that they are accounted to move fifteen Degrees in an Hour, as the fixed Stars do.

PROPOSITION V.

Having the Time of an Appearance in the Heavens with us, and with others, to find the Difference of their Longitude from ours.

THIS is easy from what hath been said. You are only to turn the Difference of Time into Degrees; counting fifteen Degrees for an Hour: and if their Hours be less than ours, then they are to the West of us, but if more, to the East.

PROPOSITION VI.

Having again the two Times in which there is any remarkable Appearance in the Heavens; to find the Difference of Longitude by the Globe or Map.

TURN the Difference of Time into Degrees, as before; and bring the one Place to the brass Meridian; and consider whether the other lies to the East or West of you, by their Hours being more or fewer, as before; if to the East count so many Degrees on the Equator easterly, and turn the Globe so many to the West, and the Meridian under the brass Meridian shows the Longitude of the other Place. This may be done better by the Index of the Hour Circle, as before. And on the Map, apply a Ruler to the Longitude of the one, and count so many Degrees on the Map to the other.

PROPOSITION VII.

To find the Longitude of the Place we are in, or our Distance from any known Meridian that is, or may be, drawn on the Globe.

THIS is the Problem whose Solution Sailors have so long wished for, from Mathematicians; and would render Navigation almost perfect, and liable to very few Errors. This for these two last Ages (in which the *Europeans* have sailed with great Labour and Success thro' all parts of the vast Ocean) hath exercised and distracted the Wits of many; and for the Solution of which the *English*, *Dutch*, and *French*, have promised each of them fifty thousand Gilders as a Reward. But none have gained it, tho' many have proposed and tried several Methods; and some have been so fond of their own Inventions as to require the Reward; but their Method being examined, hath been found very deficient, as we shall see hereafter. The *Dutch* and *Germans* express the Problem as we have done; tho' many of them use another phrase; *viz.* finding the East and West, which is quite another Thing; so great Liberty do the Vulgar take to express Things their own way, tho' ever so improperly. Thus they show us by the phrase, that they know not what Seamen mean when they speak of finding the East and West, which is a thing from the present purpose, and which Seamen know well, whatever part of the Sea they are in, by the help of their Needle, which points North and South; and without that they may by knowing the North and South know also the East and West; which are on their right and left Hand as they look to the North. But the Matter is to know how far the Meridian they are in

in is removed from the firſt Meridian on the Equator. Why then, may ſome ſay, have Seamen expreſſed themſelves thus? The Reaſon is, that the Vulgar conceiving things ſlightly give the ſame Names to things that are only like to one another; thus they call *America* the *Weſt-Indies*, becauſe it was found out a little after *India*; ſo here, becauſe the North and South is known by the Needle, and they deſire as eaſy a Way to find the Longitude which is reckoned from Eaſt to Weſt; they take it to be finding the Eaſt and Weſt Points,

WE come now to the Solution of the Problem for which ſeveral Methods have been thought on. All agree in this, that it cannot be done without ſome celeſtial Appearance of the Stars or Planets, which the Latitude itſelf requires (for as to the Dipping-Needle, that is too doubtful, and ſubject to Errors). Yet it might be done without the Appearance of the Planets, if we could make a Clock to go true at Sea.

WE have ſhown in the preceding Propoſition, that if we have two Times of a celeſtial Appearance in two Places, their Difference turned to Degrees and Minutes gives the Difference of Longitude. And ſeeing in an Ephemeris we have the Time of the Conjunction of the Planets, and of Eclipſes, their beginning, middle, and end, determined for a Place whoſe Longitude is known; if then we could find the Hour in a Place at Sea when theſe celeſtial Appearances happen, we ſhould have the Difference of that Meridian, from the Meridian for which the Planets Place, or their Conjunction with the fixed Stars, or Eclipſes, were calculated. Nor would it be hard to find the Hour of the Place at Sea, for that is determined from the Altitude of the Stars or the Point they are in: but there is no celeſtial Appearance which can be obſerved ſo accurately as to be uſeful this way.

BUT there are other Ways by which the Longitude is sought after, without the knowledge of the Hour and regarding the Planets Motions. Yet they require the knowledge of Things which are as much wanted, and so have no place here, tho' we shall explain these ways hereafter. Now the knowledge of the Time cannot be had from celestial Appearances. For Example, *Saturn* moves in the Ecliptic scarce five seconds in an Hour; and tho' they may calculate his Place to an Hour and Minute; yet because he moves so slowly he will appear as in the same Place for some Hours; and therefore we cannot compare the Hours in the two Places together; if there be only an Hour, or fifteen Degrees difference in the two Meridians: for in that short time he scarcely alters his Place.

AND so the Sun moves each Hour in the Ecliptic about two Minutes and a half; which is too slow for an Observation, tho' very accurate; and an Error of an Hour is easily committed; whereas the Sun must appear in different Places every Minute or two: for if it appear in the same Places for two Minutes, we cannot know exactly the Hour; and an Error of two Minutes will be an Error of half a Degree on the Map, which is seven *German* Miles and a half. The best Appearances (to come within a Minute or two) are; 1. An Eclipse of the Moon. 2. The Moon's Place in the Zodiac. 3. It's Distance from, or Appulse to, the fixed Stars. 4. The Moon's entring into the Ecliptic, and cutting it. 5. The Conjunction, Distances, and Eclipses of the Satellites of *Jupiter*, which have been wonderfully discovered in this Age, by the help of Telescopes; and greatly confirm the *Copernican* Hypothesis.

The first Method of finding the Longitude; by the Eclipse of the Moon.

THIS is an excellent Method, and accurate enough if there were Eclipses every Night: thus as soon as you perceive, by means of the Telescope, the beginning or end of an Eclipse of the Moon observe the Altitude of a Star, or Point in which it is; which with the Altitude before given, or then found, will give the Hour of the Night. And if the Star be in the Meridian, the Work will be the shorter. And this Hour and Minute compared with that Hour and Minute in which the Appearance is to be, by Calculation, gives the Difference of Time, and so of the Meridians, for which the Calculation was made, and where the Eclipse was seen: or, the Meridian of the Ephemeris being found in the Map, you may find the Meridian you are in, which is either to the East, if the Hours are more, or to the West if less than those in the Ephemeris.

The second Method of finding the Longitude; by the Moon's place in the Zodiac.

THO' that Method by the Eclipses of the Moon is very accurate; yet because those Eclipse are but seldom, nor all seen in all Places, the Problem is not sufficiently solved; and the Seamen will not be much the better for it; yet it is a very useful way at Land, where Mathematicians live, and can observe them truly; for thereby the Longitudes of most Places are set down in the Maps. But this second Method, by the Moon's Place in the Zodiac, may be tried frequently, tho' the Observations and Calculation are very troublesome and perplexed, because of the double Parallaxes; and an Er-

ror

ror of an Hour itſelf may creep into the Work, which will cauſe a Miſtake of about an hundred Miles. Tho' the Error will be leſs if you take the Minute when the Moon is in the Ecliptic, and find the Hour of the Night, by the Altitude of ſome remarkable Star, or by the Time it comes to the Meridian, which is better. Then from that Hour find what Point of the Zodiac or Ecliptic is in the Mid-heaven, as Aſtronomers ſpeak, or in the Meridian, as we ſhall ſhow, which compare with the Time when the Moon comes to the Meridian, by the Ephemeris; and thus we ſhall have the Hours in two Places as before, from which the Difference of the Meridians is found.

The third Method; by the Diſtance of the Moon from ſome fixed Star.

BECAUSE we cannot obſerve the Moon in the Meridian for ſome Nights before and after New Moon, it being near the Sun; and ſo the uſe of it is not ſo frequent as Seamen deſire; therefore another Method, which may be more frequently uſed, is propoſed by the appearing or removing of the Moon to or from the fixed Stars; but the Calulation is ſo troubleſome by the Parallaxes, and the Solution of oblique ſpherical Triangles, that Seamen cannot uſe it: nor will I trouble young Students with the multitude of Precepts thereto belonging; it requiring Men well verſed in Calculations to go thro' it. There is a Monk in *France* called *Duillerius*, who thinks the Difficulties here may be avoided, or eaſily overcome, by a peculiar Method of his own; having lately publiſhed a little Book, in which he profeſſes to give an uſeful Meathod to Seamen for diſcovering the Longitude; adding ſeveral other things, and dedicating the ſame to the *French* King; and afterwards (becauſe perhaps

haps he got nothing for it) to the Confederate States of *Holland*; and at this Time that I am writing he demands the Reward. In the Book he gives two Rules, tho' they are almost the same; only the first is proposed more obscurely, and is of no service to Seamen. But he contradicts *Euclid's Elements*, yet pretends, that the Error will cause no Error in Practice; and therefore in the end of the Book he adds an easier Method, by which there must be a celestial Globe exactly made, in which the Ecliptic and it's Poles are accurately placed. 2. There must be an Ephemeris for the Sun and Moon, perfectly true, at hand. The Author says he used the *Rudolphin* Tables, and found them to agree with the Heavens. 3. From these Tables must be taken the Latitude and Longitude of the Moon, for that Day in which the Observation is to be made; then applying the brass Quadrant, one end to the pole of the Ecliptic, the other to the Moon's place in the Ecliptic, observe the Latitude of the Moon upon it, and mark it; that Mark shows the Moon's place on the Globe, and it's Situation for that Day: and so from the Tables find the Moon's place for the next Day, and mark it; then take a narrow piece of Paper, of a small Length, and apply it to the Globe above those two marks (for in this the whole Art consists, as he confesses) and marking the two points on the Paper, and, applying a Ruler, draw a Line from the one to the other; and that Line will show the Moon's way in a Day. Then observe the Moon's Distance from a known Star at that Time, and taking it in Degrees and Minutes from the Equator, or Ecliptic, on the Globe, fix one point of the Compass on the Star, and with the other describe an Arch on the Moon's path, and mark where it cuts it, and bring the Quadrant to it, and you have the Moon's place in the

Ecliptic at the Time of Obſervation. Then find by the Ephemeris when the Moon will come to that Point; which being compared with the Time of Obſervation, gives the Difference of Time, and ſo of the Longitude. I omit here ſome Precepts for the Equation of the Time, &c. Thus the Author thinks to be free of the Parallaxes and Difficulties of the Refraction. There ſeems to me to be ſeveral Faults in this Method; but my Book going to the Preſs, I had not Time to examine all his Rules.

The fourth Method; by the Moon's entring the Ecliptic.

THE Moon's Path cuts the Ecliptic, in two Points, into which when it comes, 'tis ſaid to be in the Ecliptic, and from which it goes five Degrees. There muſt therefore be obſerved at Sea, the Time when the Moon comes into the Ecliptic; the Time may be alſo had when it comes to it by the Ephemeris; and the Difference of the two Times gives the Longitude: but this Method is not eaſily followed, and the Calculation is very intricate, and ſubject to Errors; and ſo can be of little uſe in the Matter.

The fifth Method; by the Satellites of Jupiter.

MOST Aſtronomers think this Method preferable to that by the Moon, as not being ſubject to the Difficulties of the Parallax; and when *Jupiter* is above the Horizon it may ſtill be uſed. There are four *Satellites* which move about *Jupiter* as their Center, which may be ſeen by a Teleſcope: this was the great Diſcovery of *Galileo*. Their proper Motion about *Jupiter* is ſwift; for they have a Motion in common with *Jupiter* about the Sun, and with the other Stars round the Earth; that next *Jupiter* goes round

round in one Day eighteen Hours and a half; the second in three Days thirteen Hours and an half; the third in seven Days two Hours; the fourth in sixteen Days eighteen Hours. Their Motion is to be calculated for every Hour; and their Motions may be found in some Books, tho' not common; and the Time of their Conjunctions with *Jupiter* (or of their immersion or emersion from his Shadow) being observed with a good Telescope, and the Time of Night when it happens; and consulting the Tables, you will find when that immersion or emersion is to be; and the Difference of the Time, gives, the Difference of the Longitude.

The sixth Method; by Clock-work.

BECAUSE all the former Methods have this Disadvantage, that they cannot be observed every Night (as is known of the Moon, and so of *Jupiter* when near the Sun); nor is it easy to make Observations of them at Sea, because of the Ship's Motion; therefore some have quitted these, and are now wholly bent upon making a Piece of Clock-work that shall go true with the Sun; and divide the Day exactly into twenty four Parts.

IF such a Thing could be made, it would render the Business easier for Seamen; who then need only to observe truly the Hour of the Place when they left it, and set their Clock to that Hour, which would still show the Hour of that Place wheresoever they went, and finding of the Hour of the Place they are in, as shall be shown; they have, as before, the two Times, which will give the Longitude of the Place they are in.

BUT tho' Artificers have been at great Pains to make such a Piece of Clock-work, yet none have had the good Luck to accomplish it; for both the Matter out of which it is made, and the Air at Sea hinders the equality of their Motions; it moving faster

faster in hot than in a cold Air. So that the Clock which the *Dutch*, wintering in *Nova Zembla*, had placed in the Houses, ceased to move; tho' they added a greater Weight. To supply this Defect some advise to bring the Clock every Day to the Hour of the Place they come at, which may be observed from the Heavens; yet a great Error will thus creep into the Work; for on the second Day the Longitude of the Places comes to be found this way, there will be some small Error, and the third Day another, and the fourth another; all which added will make the Error considerable. For Example, if in one Day there be an Error only of four Minutes, which will be in the best Clock they have yet made, the Error in the Longitude will be one Degree; and the next Day another, *&c.* Therefore this Method is justly neglected by Seamen; and at the Time I am writing, there are some at the *Hague* who promise to the States a true piece of Clock-work; but it being examined by Men skilled in these Things, it is found insufficient (*b*).

LEMMA.

(*b*) There is another great Difficulty in the use of Clocks for discovering the Longitude: because how perfect soever they may be made, yet they will shew the Hours in Places of different Latitudes, different from those of the Place they were made for. Thus for Example, if a Clock fitted for *Paris* were to approach the Equator, it would there shew the Hour slower by one twentieth Part, according to the Observations of M. *Richer**, or more than three or four Minutes, according to M. *Hayes* and *Couplet* †, then at *Paris*. And hence proceeds that Retardation of the Motion of the Pendulum of the Clock, towards the Equator, as mentioned *Chap.* iii. And Mathematicians by reasoning according to the Principles there laid down, shew how much the Motion of a Clock may be retarded, according to the Diminution of the Latitude of the Place. But as in this Matter they are obliged to

* *See Hist. Acad. Reg.* by *du Hamel*, p. 110.

† *Hist. de l'Acad. Roy.* 1700, 1701.

LEMMA.

BECAUSE in each of the foregoing Methods the Hour is to be found at the place where the Obſervations are made, we ſhall ſhow, from Aſtronomy, how that may be done; the Elevation of the Pole being given, the Sun is to be uſed by Day, and the Stars by Night, and in both Times 'tis beſt to obſerve when they come to the Meridian, and uſe a good Clock for the intermediate Time: for in half a Day there will be but a ſmall Error, if care be taken: and ſo we have no need of the Latitude, tho' 'tis wanted afterwards to find the Parallel of the Place.

BY Day we know 'tis twelve when the Sun comes to the Meridian, and then the Clock is to be brought to 12; but if the Hour be taken before twelve, bring the Clock to it; and obſerve when the Sun comes to the South, and the Clock will ſhow the Hours ſince the Obſervation, and ſo the Hour that was then.

BUT if you obſerve the Sun out of the Meridian, and take it's Altitude, you will have a ſpherical Triangle, in which is known the Complement of the Latitude, the Complement of the Declination, and the Complement of the Altitude; whence you may find the Angle between the two firſt by ſpherical Trigonometry. We ſhowed, *Prop.* xxiii. *Chap.* xxix. how to do it by the

uſe an Hypotheſis, which themſelves do not allow certain, the Proportion they aſſign cannot be relied on, for diſcovering the Longitude of Places with any exactneſs. It remains therefore to be diſcovered, by accurate Obſervations made in all Parts, in what Proportion Clocks are retarded according to the different Latitudes; that the Hour ſhewn may be reduced to the true Hour of the Place departed from.

Globe,

Globe, which may be sufficient for a Geographer; but Seamen must find it by Calculation: tho' some find it by an Universal Planisphere; but I fear there will be an Error of some Minutes. By Night the Stars are to be used; and some one or other may be found then in the South, or we may wait 'till one comes to it; then take the right Ascension of the Sun and Star, substract the former from the latter; but if greater, add it's Complement to three hundred and sixty to the Star's Ascension; and turn the Degrees to Hours and Minutes.

PROPOSITION VIII.

To explain other Methods of finding the Longitude, which properly give us not the Longitude itself, but the Point we are in, whose Longitude is wanted, which is of use to determine the Longitude.

The first Method.

Having the Distance of two Places, and the Latitude of both Places, to find the Difference of their Longitude; or the Point of the one being given in the Map or Globe, to find the other.

IF we use trigonometrical Calculation, we must find the Angle in the spherical Triangle, which hath three sides known, *i. e.* the Angle between the Complements of the two Latitudes, or opposite to the distance turned to degrees.

BUT by the Globe and Map thus. Take the Distance, turned to Degrees, with the Compasses on the Globe, and fixing one Leg at the Place given, cut the Parallel of the other in a Point thro' which a Meridian being drawn, will be the Meridian of the other. But Maps, even Sea-Charts, are

are not so proper or ready for this Method, as not giving the Distance accurately.

The second Method.

Having the Point given, that one Place lies in from another, and the Latitude of both Places, to find the Longitude of the other, and it's Place on the Globe and Map.

BY the Point it is in we understand the Angle between the Meridian of the one, and a Line from the one Place to the other. By Trigonometry, find the Angle between the two Complements of the two Latitudes, and you have the Difference of Longitude.

ON the Globe thus: bring the known Place to the Zenith, and there apply the Quadrant of Altitude; and having drawn the Parallel of the other Place, bring the Quadrant to the Point; and where it cuts the Parallel is the other Place.

THE same way on the Map: draw the Parallel of the unknown Place, then draw a Line from the given Place to the Point in which the other is; and where that Line cuts the Parallel is the Place. If the Point a Ship sails on be enquired we must proceed otherwise, as in *Chap.* xxix.

The third Method.

Having the Point a Place lies in from another whose Latitude is known, with their Distance, to find the Longitude of that Place, and it's Situation on the Globe and Map.

BY Trigonometry; having the Complement of the Latitude, and the Distance in Degrees, and the Angle included between them, by having the Point

given; find the Angle opposite to the Distance, which will be the Difference of Longitude.

ON the Globe and Sea-Charts thus: bring the Place to the Zenith, and apply the Quadrant there, and bring it to the Point on the Horizon; then count the Distance on the Quadrant, from the Zenith; and a Meridian from the Pole thro' the Extremity of the Arch of Distance, is the Meridian the other Place is in. We shall show how this may be done by the Planisphere in *Chap.* xxxiii. for the Globe is not so useful at Sea.

THE same way may be used to find the Place on the Sea-Charts; but 'tis not so accurate, as we shall see in the following Chapter.

The fourth Method.

Having the Distance of an unknown Place from two other Places whose Distance from them is known.

ON the Globe: take one Distance turned to Degrees from the Equator, and one Foot being in that one Place, describe an Arch, and with the Distance of the other, and one Foot in the other Place, cut that Arch; and the Point of Intersection is the other Place.

AND the same way on the Map; only the Distance is not to be turned to Degrees, but taken from the scale of Miles; but if the Place be very remote there will be a considerable Error: for the Maps do not perform this accurately.

TO work by Calculation is difficult, and requires a Figure; and is better learned from a Master than by reading.

The fifth Method.

Having two Places on the Earth, and the Points in which a third Place is situated from them, to find it's Place on the Globe and Map, and it's Longitude by Calculation.

ON the Globe: bring one Place to the Zenith, and apply there the end of the Quadrant of Altitude; bring it to the Point on the Horizon; and draw a Line (or a vertical Circle from the Zenith) along the Edge of the Quadrant; and do the same with the other Place; and where the Quadrant cuts the first vertical Circle is the Place of the other.

AND the very same way may be used for finding it on the Map.

THE Calculation of it we leave to a Master, if he find a Scholar that is capable of it.

BUT enough is said of finding the Longitude, whose great Use we have shown under *Prop.* ii.

WE here add a Table of the Latitude and Longitude of the chief Places of the Earth, that Students may have wherewith to exercise themselves. This Table is also useful in every Part of Geography. The Author's Table, which was very erroneous, is here omitted; and a new and exact one, agreeable to more late and careful Observations, added in it's stead.

A TABLE of the Latitude and Longitude of the most remarkable Places in the World, from the latest and best Observations, the Longitude accounted from the Meridian of London.

Note, *All the Places that have* S *annexed to their Latitude, are in South Latitude, and all the rest are North from the Equinoctial. Also, all the Places whose Longitude are marked* W, *are in West Longitude from the Meridian of* London, *and all the rest East.*

Names of Places.	Latitude			Longitude		
A	D.	M.		D.	M.	
ABbeville, Picardy, France	50	9	N	2	24	E
Achin, Sumatra East Indies — — —	4	40	N	93	15	E
Adrianople, Turkey in Europe — —	43	33	N	27	24	E
Agra, a Capital in the Mogul's Empire —	29	0	N	79	24	E
Aix, Provence France	43	4	N	5	44	E
Aix la Chapelle Germany — — —	50	48	N	7	0	E
Aleppo, Levant Asia	37	0	N	41	20	E
Alexandria, Egypt Africa — — — —	31	25	N	30	50	E
Alexandretta, or Scanderoon — —	37	10	N	37	50	E
Algiers, Barbary Africa — — — —	36	20	N	2	10	E

2 Amiens

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Amiens, Picardy Fr.	49	30	N	2	50	E
Amſterdam, Holland	52	29	N	5	4	E
Ancona, Italy — —	43	30	N	14	30	E
Antibe, Provence Fr.	43	15	N	8	9	E
Antwerp, Brabant -	51	16	N	4	10	E
Appenrade, Sleſwic Denmark —— —	55	26	N	10	30	E
Archangel, Ruſſia —	64	50	N	40	10	E
Arica, Peru South America ———	18	50	S	74	50	W
Arles, Provence Fr.	43	15	N	4	40	E
Arras, Artois France	50	16	N	2	30	E
Aſtracan, by the Caſpian Sea Muſcovy	46	50	N	51	30	E
Athens, Greece ——	37	25	N	23	40	E
Avignon, Provence France —— ——	43	15	N	4	40	E
Auſburg, Suabia Germany — — — —	47	55	N	10	45	E
B						
BAbylon, Chaldea	31	56	N	43	50	E
Baden, Suabia Germany — — —	48	38	N	8	0	E
Bagdat Meſopotamia	33	0	N	45	20	E
Baldivia, Chili South America — — —	40	0	S	78	0	W
Barbadoes, Weſt-Indies — — — —	13	10	N	59	48	W
Barcelona, Catalonia Spain —— ——	41	10	N	2	0	E

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Barleduc, Champagne France	48	44	N	4	5	E
Baſil, Switzerland	47	34	N	8	4	E
Batavia, Java E. Ind.	6	15	S	100	50	E
Bayonne, Gaſcony Fr.	43	30	N	1	10	W
Belgrade, Servia	45	0	N	18	20	E
Bengal, India	21	0	N	88	0	E
Bergamo, Italy	45	43	N	9	45	E
Bergen, Norway	60	0	N	5	25	E
Berlin, Upper Saxony Germany	52	10	N	13	30	E
Bilboa, Biſcay Spain	43	10	N	3	0	E
Bologna, Italy	44	30	N	11	40	E
Bologne, Picardy Fr.	50	36	N	1	50	E
Boſton, New-Engl.	42	10	N	67	0	W
Bourdeaux, Guienne France	44	55	N	0	45	E
Brandenburg, Upper Saxony Germany	52	10	N	12	30	E
Breſt, Bretagne Fr.	48	34	N	4	28	W
Bremen, Weſtphalia Germany	53	0	N	8	48	E
Breſlaw, Bohemia Germany	51	5	N	16	35	E
Briſtol, England	51	33	N	2	34	W
Brill, Holland	51	55	N	6	15	E
Bruges, Flanders	51	15	N	3	0	E
Brunſwic, Germany	51	55	N	11	30	E
Bruſſels, Flanders	50	48	N	4	5	E
Buda, lower Hungary	47	0	N	16	55	E

Cadiz

Names of Places.	Latitude			Longitude		
C	D.	M.		D.	M.	
CAdiz, Andalusia Spain - - - -	36	5	N	5	40	W
Cairo, Egypt Africa	30	10	N	31	30	E
Cagliari, Sardinia - - -	39	10	N	9	26	E
Calais, France - - - -	50	57	N	1	50	E
Calmar, Sweden - - -	56	55	N	17	20	E
Calecute, East Indies	11	0	N	74	50	E
Cambodia, India - -	10	20	N	108	0	E
Cambray, France - -	50	10	N	3	15	E
Candia, in Candia Isl.	34	55	N	24	50	E
Canterbury, England	51	10	N	1	6	E
Candia, Ceylon East Indies - - - - - - - -	7	30	N	80	30	E
Cape of Good Hope -	34	15	S	19	50	E
Cape Verd - - - - - - -	14	30	N	16	26	W
Cartagena, Spain - - -	37	0	N	0	28	E
Carthage, Africa - - -	35	0	N	11	0	E
Catanea, Sicily - - -	37	20	N	15	15	E
Ceuta, Africa - - - -	35	50	N	5	27	W
Ceylon, East India -	7	50	N	83	20	E
Christianstadt, Gothland Sweden - - - -	56	35	N	14	36	E
Cochin, Malabar Ind.	10	0	N	75	18	E
Cochin, China E. Ind.	13	0	N	107	0	E
Cologne, Germany -	50	40	N	7	10	E
Compostella, Galicia Spain - - - - - - - - -	42	45	N	8	15	W
Constantinople - - - -	41	40	N	29	40	E
Copenhagen, Zeland Denmark - - - - - -	55	40	N	12	35	E

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Cork, Ireland — —	51	45	N	8	0	W
Corinth, Morea Turky	38	0	N	22	25	E
Cormandel, India —	8	0	N	78	20	E
Cracow, Poland ——	50	15	N	20	50	E
Cremona, Italy — —	45	10	N	10	32	E
Cuſco, Peru —— —	12	25	S	73	40	W
Cyprus Iſland, Levant	35	0	N	34	0	E
D						
DAntzic, Poland	54	25	N	19	30	E
Dardanels, Tur.	40	0	N	28	0	E
Delft, Holland — —	52	10	N	4	10	E
Derbent, by the Caſpian Sea —— ——	42	0	N	50	0	E
Dieppe, France — —	49	56	N	0	57	E
Dort, Holland — —	51	45	N	4	30	E
Doway, Flanders —	50	12	N	3	30	E
Dreſden, Saxony —	51	6	N	13	50	E
Droutheim, Norway	63	0	N	10	15	E
Dublin, Ireland ——	54	50	N	7	20	W
Dunkirk, France —	51	7	N	2	30	E
Durazzo Albania Tur.	40	40	N	17	45	E
Duſsledorp, Weſtphal.	51	0	N	7	5	E
E						
EDinburgh, Scotl.	55	56	N	3	0	E
Ebbing Poland	54	20	N	20	30	E
Elſingborg, Schonen Sweden — — ——	56	0	N	13	10	E
Elſineur, Zeland Denmark —— —— —	56	0	N	13	6	E
Embden, Weſtphalia Germany — — —	53	10	N	7	15	E

Enchuy-

Names of Places,	Latitude D.	M.		Longitude D.	M.	
Enchuysen, Holland	52	50	N	4	30	E
Ephesus, Natolia Asia	37	50	N	27	35	E
Erfort, Saxony Germ.	50	40	N	11	30	E
F						
FErrara, Italy ——	44	45	N	12	10	E
Ferro, Canaries	28	5	N	18	10	W
Fez, Barbary Africa	33	15	N	3	50	E
Florence, Tuscany Italy — —— ——	43	40	N	11	35	E
Fontarabia, Biscay Sp.	43	0	N	1	40	W
Frankford, on the Oder Germany ——	52	28	N	14	35	E
Frankfort, on the Main Germany —	49	45	N	9	45	E
Freiberg, Suabia Germany ————	47	50	N	8	10	E
Furstenburg, Suabia Germany — — —	47	15	N	9	15	E
G						
GAllipoli, Romania Turkey —	40	55	N	28	20	E
Geneva, Savoy Italy	46	15	N	6	12	E
Genoa, Italy ———	44	25	N	9	22	E
Ghent, Flanders —	51	6	N	3	35	E
Gibralter, Spain ——	35	50	N	5	35	W
Giron, Catalonia Sp.	41	45	N	3	12	E
Glasgow, Scotland	56	20	N	4	18	W
Gnesna, Poland ——	52	25	N	18	32	E
Goa, East-Indies —	15	30	N	73	50	E
Gombroon, Persian Gulph — — — —	7	10	N	56	0	E

Gotten-

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Gottenburg, Sweden	57	30	N	12	0	E
Granada, Granada Sp.	36	20	N	2	45	E
Grenoble, Dauphiné France - -	45	10	N	5	40	E
Grodno, Lithuania Poland - -	53	25		25	4	E
Groeningen, Holland	53	5	N	5	45	E
Guadaloupe, America	14	0	N	62	15	W
H						
HAgue, Holland	52	10	N	4	0	E
Hamburg, Germany - -	53	30	N	10	0	E
Hanover, Saxony Germany - -	52	16	N	9	0	E
Harlem, Holland -	52	25	N	4	15	E
Heidelburg, Lower Rhine Germany -	49	12	N	8	45	E
St Helen's Iſland -	15	55	S	7	0	W
Helmſtadt, Saxony Germany - -	51	52	N	12	10	E
Hildeſheim, Weſtphalia Germany -	51	45	N	10	15	E
Hoen, Zolern Suabia Germany - -	48	40	N	9	10	E
I						
ST JAgo, Spain -	42	58	N	9	52	W
James-Town, Virginia Nor. America - - -	37	10	N	75	0	W
Jeruſalem, Paleſtine Aſia - -	32	44	N	35	15	E

Ingol-

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Ingolstadt, Bavaria Germany —— —	48	32	N	13	0	E
Inspruc, Austria Germany —— ——	47	40	N	14	45	E
Ispahan, antient Parthia Persia —— —	33	0	N	53	10	E
Juliers, Westphalia	50	20	N	6	45	E
K						
KAffa, Crim Tartary —— —	46	0	N	36	50	E
Kaminiack, Podolia Poland —— ——	49	20	N	24	35	E
Kargapol, Russia —	61	30	N	42	15	E
Kexholin, Finland Sweden ———	61	20	N	31	0	E
Kiow, Ukrain Poland	50	30	N	32	45	E
Koningburg, Prussia Poland —— ——	54	55	N	22	15	E
Konizeek, Poland —	54	15	N	18	50	E
L						
LAnsperg, Poland	52	55	N	15	25	E
Landau, Suabia Germany — — —	48	50	N	8	10	E
Laodecia, Natolia Asia	38	10	N	29	30	E
Leghorn, Italy — —	43	40	N	11	10	E
Lemburg, Poland —	49	50	N	25	15	E
Leopoldstat, Hungary	48	45	N	18	40	E
Lepanto, Achaia Turky — — — — —	38	30	N	20	40	E
Lewarden, W. Friesl.	53	0	N	6	30	E
Leyden, Holland —	52	10	N	4	30	E

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Leipſic, Germany	50	50	N	12	50	E
Liege, Spaniſh Provinces — — — —	50	25	N	5	35	E
Lima, Peru South America — — — —	11	30	S	78	40	W
Limburg, Spain ——	50	20	N	6	20	E
Lintz, Auſtria Germ.	48	10	N	14	30	E
Liſle, Flanders — —	50	40	N	2	50	E
Liſbon, Portugal ——	38	45	N	8	20	W
Livorn, *ſee* Leghorn						
LONDON *Metropolis* of England — —	51	32	N	00	00	
Loretto, Tuſcany Italy	43	36	N	14	38	E
Lubeck, Holſtein Denmark — — —	54	10	N	11	20	E
Lublin, Poland — —	51	18	N	25	0	E
Lucerne, Switzerland	46	42	N	8	25	E
Lunden, Gothland Sweden —— ——	55	30	N	13	25	E
Luxemburg, Saxony Germany — — —	53	10	N	10	40	E
Luxemburg, France	49	20	N	6	12	E
Lyons, Lyonois Fr.	45	40	N	4	40	E
M						
MAdagaſcar ——	19	29	S	43	55	E
Madrid, New Caſtile Spain — —	40	0	N	3	28	W
Maeſtricht, Spaniſh Provinces —— —	50	34	N	5	45	E
Magdeburg, Saxony Germany — — —	51	45	N	12	30	E

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Majorca, in the Mediterranean	39	00	N	2	30	E
St Maloes, Bretagne France	48	38	N	2	20	W
Malaga, Granada Sp.	36	00	N	3	56	W
Malta, near Sicily Mediterranean	35	50	N	14	00	E
Malucca, in the East Indies	2	8	N	100	25	E
Mantua, Italy	45	16	N	11	40	E
Marpurg, Germany	50	30	N	8	50	E
Marseilles, Provence France	43	15	N	5	40	E
Martinico Island, W. Indies	14	44	N	60	55	W
Mentz, Germany	49	44	N	8	15	E
Messina, Sicily	38	10	N	15	40	E
Metz, Lorrain Germ.	48	50	N	6	6	E
Mexico, N. America	10	00	N	104	0	W
St Michael, *see* Archangel						
Milan, Italy	55	45	N	24	0	E
Minorca Island, Mediterranean	39	10	N	4	0	E
Mittau, Courland	56	25	N	25	0	E
Mocha, China	22	13	N	116	35	E
Modena, Italy	44	30	N	11	45	E
Montpelier, Languedoc France	43	28	N	4	0	E
Moscow, Capital of Moscovy	55	30	N	39	30	E

Mousol,

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Mousol, near old Nineveh — — — —	34	32	N	43	0	E
Munster, Westphalia Germany — — —	51	45	N	7	45	E
Munchen, or Munic Bavaria Germany -	47	45	N	11	35	E
N						
NAmur, Flanders	50	10	N	4	50	E
Nancy, Lorain France — — — —	48	32	N	6	40	E
Nantz, Bretagne Fr.	47	12	N	1	30	W
Nankin, China — —	31	0	N	118	30	E
Naples Italy — — —	41	45	N	14	50	E
Narva, Livonia — —	58	55	N	30	30	E
Narbonne, Languedoc France — —	42	50	N	3	0	E
Nassau, upper Rhine Germany — — —	50	0	N	8	0	E
New Piedmont, Italy	43	40	N	7	10	E
Nismes, Languedoc France — — — —	43	30	N	4	30	E
Norwich, England -	52	45	N	1	28	E
Norkoping, Gothland Sweden —— ——	58	20	N	17	30	E
Notteburg, Ingria Sweden — ——— —	60	0	N	32	10	E
Nuremburg, Franconia Germany ——	49	0	N	11	15	E

Oleron,

Names of Places.	Latitude D.	M.		Longitude D.	M.	
O						
OLeron, Gascony France ——	43	0	N	3	20	W
Onspack, or Anspec Franconia Germ.	48	50	N	10	32	E
Orange, Provence France ———	44	10	N	14	45	E
Oran, Barbary Africa	35	30	N	0	5	W
Ormus, Persia ——	27	30	N	61	30	E
Osnaburg, Westphalia Germany ———	51	10	N	8	20	E
Oudenard, Flanders	50	46	N	3	20	E
Oxford, England —	51	48	N	1	12	E
P						
PAdua, Italy —	35	32	N	12	25	E
Paderborn Westphalia Germany —	51	30	N	9	0	E
Palermo, Sicily ——	37	26	N	13	45	E
Pampelona, Spain —	42	30	N	11	15	E
Panama, America —	1	10	S	82	30	W
Paris, France ——	48	45	N	2	20	E
Parma, Italy ———	44	42	N	11	0	E
Pekin, China — —	39	52	N	110	50	E
Perpignan, Catalonia Spain ————	42	30	N	3	0	E
Pergamos, Natolia Asia —————	37	50	N	29	10	E
Peter Waradin, Sclavonia ————	45	0	N	17	40	E
Philipopoli, Romania Turkey ———	42	30	N	24	35	E

Philadel-

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Philadelphia, Natolia Aſia — — —	38	35	N	29	35	E
Pignerol, upper Dauphiné France — —	44	48	N	7	32	E
Piombino, Tuſcany Italy — — —	42	54	N	11	10	E
Piſa, Tuſcany Italy	43	55	N	11	12	E
Placentia, Parma Italy	44	50	N	10	15	E
Pleſkow, Ruſſia —	58	10	N	33	55	E
Poictiers, Orleanois France — — — —	46	30	N	0	20	E
Port, or Oporto Portugal — — — —	40	52	N	7	50	W
Port-Royal, Jamaica	17	40	N	75	55	W
Prague, Bohemia —	50	0	N	14	25	E
Preſburg, Hungary —	48	22	N	15	30	E
Q						
QUebec, Canada	47	10	N	70	15	W
R						
RAguſa, Dalmatia Turky —	42	25	N	16	30	E
Ratiſbon, Bavaria —	48	34	N	12	10	E
Regio, Calabria Italy	38	40	N	16	10	E
Rheims, Champagne France — — — —	49	20	N	3	55	E
Rhodes, Iſland Archipelago — — —	35	30	N	29	15	E
Riga, Livonia — —	57	0	N	24	48	E
Roan, France — —	49	27	N	0	57	E
Rochel, Orleanois Fr.	45	55	N	0	50	W

Names of Places.	Latitude D.	M.		Longitude D.	M.	
ROME, Italy ——	42	8	N	13	7	E
Roses, Catalonia Sp.	41	50	N	3	30	E
Rostock, Germany—	54	10	N	12	50	E
Rotterdam, Holland	51	50	N	4	12	E
S						
SAltsburg, Bavaria Germany ——	47	20	N	13	26	E
Salamanca, Leon Sp.	40	45	N	4	50	E
Salonichi, *or* Thessalonica Turkey ——	40	42	N	22	45	E
Sallee, Africa — —	22	25	N	7	45	E
Samarcand, Tartary -	40	0	N	63	45	E
Saragossa, Arragon Sp.	41	20	N	0	45	W
Sardis, Natolia Asia	38	10	N	29	5	E
Scanderoon, *see* Alexandretta.						
Scaffhausen, Switzerland Germany ——	47	28	N	8	45	E
Selines, *see* Athens.						
Seville, Andalusia Sp.	37	0	N	5	0	W
Siam, East Indies —	14	5	N	100	50	E
Sleswic, Denmark -	55	57	N	9	40	E
Smolensko, Muscovy	54	55	N	33	30	E
Smyrna, Natolia Asia	38	4	N	29	6	E
Soissons, France ——	49	20	N	3	30	E
Spires, upper Rhine Germany — — —	49	0	N	8	10	E
Stetin, Pomerania —	53	28	N	14	30	E
Stockholm, Sweden	59	30	N	19	5	E
Strasburg, Germany -	48	17	N	7	52	E
Syracuse, Sicily ——	35	15	N	15	0	E

Names of Places.	Latitude D. M.			Longitude D. M.		
T						
TAngier, Barbary Africa — —	35	45	N	6	0	W
Tarragon, Catalonia Spain ——— ——	40	55	N	1	20	E
Temeſwaer, Hungary	45	30	N	18	40	E
Tetuan, Africa —	35	30	N	5	30	W
Tolouſe, Languedoc France —— ——	43	15	N	1	45	E
Thorn, Poland — —	53	0	N	19	32	E
Thyatira, Natolia Aſia —— —— ——	38	28	N	28	32	E
Tyrol, Auſtria Germ.	46	15	N	10	50	E
Toledo, New-Caſtile Spain ——— ——	39	30	N	3	30	W
Torneo, or Torno Lapland —— ——	65	50	N	23	30	E
Tours, Orleanois Fr.	47	10	N	0	56	E
Toulon, Provence Fr.	43	0	N	6	8	E
Tournay, Flanders	50	35	N	3	28	E
Trent, Auſtria Germ.	45	50	N	11	36	E
Treves, *or* Triers, lower Rhine Germ.	49	30	N	6	42	E
Tripoly, Barbary Afr.	33	5	N	13	50	E
Tubingen, Germany	48	34	N	9	20	E
Tunis, Barbary Afr.	35	30	N	12	40	E
Turin, Piedmont Italy	44	50	N	7	42	E
V						
VAlence, Dauphiné France	45	0	N	4	52	E
Valencia, Spain — —	39	15	N	0	10	E

Vallado-

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Valladolid, Old Castile Spain — —	41	28	N	3	50	W
Vendosme, Orleanois France — — —	47	45	N	1	6	E
Venloe, Gelderland	51	10	N	6	8	E
Venice	45	36	N	12	50	E
Verdun, Lorrain Germany — — — —	49	10	N	5	20	E
Verona, Italy — —	45	25	N	12	0	E
Vienna, Austria Germany — —	48	12	N	16	45	E
Ulm, Suabia Germ.	47	55	N	10	8	E
Upsal, Sweden — —	59	55	N	18	30	E
Urbino, Italy — —	43	44	N	13	15	E
Utrecht, Holland —	52	0	N	5	0	E
W						
WArsaw, Poland	52	10	N	22	0	E
Waradin, *see* Peter Waradin						
Wardhuys, Norway	71	8	N	29	0	E
Waterford, Ireland	53	0	N	7	8	W
Weimer, Saxony Germany — — — —	50	42	N	12	5	E
Wesel, Westphalia Germany — — —	51	32	N	6	30	E
Wiborg, Jutland Denmark — — —	56	25	N	9	20	E
Wiborg, Finland Sweden — — — —	60	50	N	30	0	E
Wisbuy, Gothland Sweden — —	57	30	N	20	0	E

Names of Places.	Latitude D.	M.		Longitude D.	M.	
Wittenburg, Saxony Germany ———	51	28	N	13	15	E
Wolfembuttle, Brunſwic Germany ——	51	50	N	10	45	E
Wormes, Germany -	49	12	N	8	28	E
Wirtſburg, Franconia Germany ———	49	20	N	10	10	E
Y						
YOrk, England -	53	20	N	0	48	E
Yvica, Mediterranean — —— —	38	40	N	1	10	E
Z						
ZEll, Lunenburg Germany ——	52	30	N	10	26	E
Zutphen, Gelderland Holland ———	52	4	N	6	6	E

THE great Uſe of the Table of Latitudes, we have ſufficiently explained in the preceding Propoſition; and alſo the famous Uſe of the Longitudes of Places in the end of *Prop.* iii. of this Chapter. For Example, having the Hour when an Eclipſe is to be in one Place, or when the Sun enters *Aries*, or when the Sun and Moon are in Conjunction, or the Hour of the Appulſe of the Moon to a fixed Star; to find the Hour when the ſame will happen in another Place, whoſe Longitude is marked in the Tables. This is done by turning the Difference of Longitude into Hours, and adding it to the other Place, if leſs, but ſubſtracting if more; which will give the Hour when the Phænomenon happens in the other Place.

BUT

BUT the principal Use of this Table will appear in the following Chapter.

AND seeing the Use of the Declination and right Ascension of the fixed Stars is very necessary in Geography and Navigation; we here add a Table of them; for the year 1710. 'Tis known in Astronomy, that there is a Change in these, by reason of the Motion of the fixed Stars on the Axis of the Ecliptic. 'Tis proper to have a Table of a great many Stars; for the same Stars are not always above the Horizon at Night. We add them here, chiefly for the Practice of young Students, that they may work the Problems. This belongs to Astronomy, but is also of great Use in Geography and other Sciences.

BY Astronomy we find the Declination and right Ascension for each Year. The Tables follow.

A Table of the Sun's Right Ascension.												
Days.	Jan. ☉ Right Ascension		Febr. ☉ Right Ascension		March ☉ Right Ascension		April ☉ Right Ascension		May Right Ascension		June ☉ Right Ascension	
	H.	M	H	M	H	M	H.	H	M.	M	H	H.
1	19	36	21	43	23	29	01	22	03	15	05	20
2	19	40	21	47	23	33	01	26	03	19	05	24
3	19	44	21	51	23	37	01	30	03	23	05	28
4	19	49	21	55	23	40	01	34	03	27	05	32
5	19	53	21	59	23	44	01	37	03	31	05	37
6	19	57	22	03	23	47	01	41	03	35	05	41
7	20	01	22	07	23	51	01	45	03	39	05	45
8	20	05	22	11	23	54	01	48	03	44	05	49
9	20	09	22	15	23	58	01	52	03	47	05	53
10	20	14	22	18	00	02	01	55	03	51	05	57
11	20	18	22	22	00	06	01	59	03	55	06	01
12	20	23	22	26	00	09	02	03	03	59	06	05
13	20	27	22	30	00	13	02	07	04	03	06	09
14	20	31	22	34	00	16	02	11	04	07	06	13
15	20	35	22	37	00	20	02	14	04	11	06	18
16	20	39	22	41	00	24	02	18	04	15	06	22
17	20	43	22	45	00	27	02	22	04	19	06	27
18	20	47	22	49	00	31	02	26	04	23	06	30
19	20	51	22	53	00	34	02	30	04	27	06	34
20	20	55	22	56	00	38	02	33	04	31	06	39
21	20	59	23	00	00	42	02	37	04	35	06	42
22	21	04	23	04	00	45	02	41	04	39	06	47
23	21	08	23	07	00	49	02	45	04	43	06	51
24	21	12	23	11	00	53	02	49	04	47	06	55
25	21	16	23	15	00	56	02	52	04	51	06	59
26	21	20	23	18	01	00	02	56	04	55	07	03
27	21	24	23	22	01	04	03	00	04	59	07	07
28	21	28	23	26	01	07	03	04	05	03	07	11
29	21	32			01	11	03	08	05	07	07	15
30	21	36			01	15	03	11	05	12	07	20
31	21	39			01	18			05	16		

A Table of the Sun's Right Ascension.												
Days.	*July* ☉ Right Ascension		*August* ☉ Right Ascension		*Septem.* ☉ Right Ascension		*October* ☉ Right Ascension		*Novem.* ☉ Right Ascension		*Decem.* ☉ Right Ascension	
	H.	M.	H.	M	H.	M	H.	M.	M.	M	H.	M.
1	07	24	09	26	11	20	13	09	15	08	17	16
2	07	28	09	30	11	24	13	13	15	12	17	21
3	07	32	09	34	11	27	13	16	15	16	17	26
4	07	36	09	38	11	31	13	20	15	20	17	30
5	07	40	09	41	11	34	13	23	15	24	17	35
6	07	44	09	45	11	37	13	27	15	28	17	39
7	07	48	09	49	11	42	13	31	15	32	17	43
8	07	52	09	52	11	45	13	35	15	37	17	47
9	07	56	09	56	11	49	13	39	15	41	17	52
10	08	00	09	59	11	50	13	42	15	46	17	57
11	08	04	10	03	11	56	13	46	15	50	18	01
12	08	08	10	07	12	00	13	50	15	54	18	06
13	08	12	10	11	12	03	13	54	15	59	18	10
14	08	16	10	15	12	07	13	58	16	03	18	15
15	08	20	10	18	12	10	14	01	16	08	18	20
16	08	24	10	22	12	14	14	05	16	12	18	24
17	08	28	10	26	12	18	14	09	16	16	18	29
18	08	32	10	29	12	21	14	13	16	20	18	34
19	08	36	10	33	12	25	14	17	16	24	18	38
20	08	40	10	36	12	28	14	21	16	29	18	42
21	08	44	10	40	12	32	14	25	16	33	18	46
22	08	48	10	44	12	36	14	29	16	37	18	50
23	08	52	10	48	12	39	14	33	16	41	18	55
24	08	56	10	51	12	43	14	37	16	45	18	59
25	08	59	10	54	12	46	14	40	16	50	19	04
26	09	03	10	58	12	50	14	44	16	54	19	08
27	09	07	11	02	12	54	14	48	16	58	19	12
28	09	11	11	05	12	58	14	52	17	03	19	17
29	09	15	11	09	13	02	14	56	17	07	19	21
30	09	18	11	12	13	06	15	00	17	12	19	26
31	09	22	11	16			15	04			19	31

A Table shewing the Right Ascension, Declination, and Magnitude of the Principal Fixed Stars.

Names of the Stars.	Magnit.	Right Ascens. H.	Right Ascens. M.	Declination. D.	Declination. M.	
Pole Star	2	00	32	87	51	N
Girdle of Andromeda	2	00	50	33	50	N
Bright Star of Aries	2	01	52	22	10	N
Medusa's Head	2	02	49	39	54	N
Right side of Perseus	2	03	05	48	52	N
Aldebaran, or Bull's Eye	1	04	18	15	55	N
Capella, or the Goat	1	04	55	45	41	N
Bright Foot of Orion	1	05	01	08	33	S
Middle Star in Orion's Belt	3	05	20	01	25	S
Orion's Right Shoulder	1	05	39	07	19	N
Auriga's Right Shoulder	2	05	44	44	53	N
Bright Foot of Gemini	2	06	19	16	38	N
Syrius, or the Great Dog	1	06	33	16	21	S
Castor, or Northermost Twin	2	07	16	32	27	N
Procyon, or the Little Dog	2	07	24	05	54	N
Pollux, or Southermost Twin	2	07	25	28	39	N
Hydra's Heart	1	09	14	07	29	S
Lyon's Heart, or Regulus	1	09	54	13	16	N
The Lower of the Pointers	2	10	41	57	50	N
The Upper of the Pointers	2	10	43	63	13	N
Lyon's Tail	1	11	31	16	05	N
Upper of two last in the Square of the Great Bear	2	12	02	58	34	N
Last but two in the Great Bear's Tail	2	12	40	57	27	N
Virgin's Spike	1	13	11	09	44	S

Last

Names of the Stars.	Magnit.	Right Ascens. H.	M.	Declination. D.	M	
Last but one in the Great Bear's Tail	2	13	10	56	21	N
Last in the Great Bear's Tail	2	13	34	50	42	N
Arcturus	1	14	02	20	38	N
South Ballance	2	14	32	14	54	S
Foremost Guard	2	14	51	75	15	N
Brightest of the Crown	2	15	21	27	38	N
Brightest of the Serpent's Neck	2	15	33	07	18	N
Antares, the Scorpion's Heart	1	16	12	25	47	S
Head of Hercules	3	17	02	14	43	N
Ophincus, or Serpent's Head	3	17	22	12	47	N
Lyra, or the Harp	1	18	27	38	33	N
Swan's Bill	3	19	17	27	29	N
Vulture, or Eagle's Heart	2	19	34	08	10	N
Swan's Tail	2	20	30	44	19	N
Mouth of Pegasus	3	21	27	08	39	N
Fomelhaut	1	22	41	31	03	S
Marchab, or Pegasus Wing	2	22	48	13	44	N
Scheat, or Pegasus Leg	2	22	50	26	36	N
Cephus's Knee	3	23	20	76	07	N
Andromeda's Head	2	23	53	27	35	N
End of Pegasus Wing	2	23	57	13	39	N

The Explanation and Use of the Tables of the Sun's Right Ascension, and of the Right Ascension and Declination of the fixed Stars.

FOR the Table of the Sun's Right Ascension, seek the Month at the Top, and the Day in the left Hand Column, and in the common Angle, is the Sun's Right Ascension. *Example*, on the 17th of *July*, the Sun's Right Ascension is 8 Hours 38 Minutes.

IN the Table of fixed Stars, the first Column is the names of the Stars; the second, the Magnitude; the third, the Right Ascension in Hours and Minutes; and the fourth, the Declination in Degrees and Minutes. *Example*, the *Virgin's Spike* is of the first Magnitude, Right Ascension 13 Hours 11 Minutes, Declination 9 Degees 44 Minutes South, *&c.*

I. *To find the time of a Star's coming upon the Meridian.*

SUBSTRACT the Right Ascension of the Sun, from the Right Ascension of the Star, (adding 24 Hours to the Right Ascension of the Star, if Substraction cannot otherwise be made) the remainder is the time of the Star's coming to the Meridian.

EXAMPLE. I desire to know what time the Great Dog comes to the Meridian, *December* the 25th.

	H.	M.
Right Ascension of the Great Dog —	6	33
Right Ascension of the Sun — ——	19	4
Remainder (24 Hours being added to the Right Ascension of the Great Dog.) —— ———— ——	11	29

THE Great Dog souths 29 Minutes past 11 at Night.

II. *By the Altitude of a Star, when upon the Meridian, to find the Latitude of the Place.*

Note, *In North Latitude, those Stars whose North Declination exceed the Complement of Latitude, may be observed under the Pole.*

THIS may be reduced to four Rules.

1. WHEN

1. WHEN the Star is between the Horizon and the Equinoctial, substract the Declination from the Complement of Altitude (commonly called the Zenith Distance) the Remainder is the Latitude of the Place. *Example.*

	D.	M.
Suppose the Complem. of Altitude be	70	30
The Declination South —— ——	40	00
The Latitude is —— —— ——	30	30

2. WHEN the Sun or Star is between the Equinoctial and the Zenith, add the Complement of Altitude to the Declination, the Sum is the Latitude of the Place. *Example.*

	D.	M.
Let the Complement of Altitude be	35	00
The Declination North —— ——	10	00
The Latitude is —— —— —— ——	45	00

3. WHEN the Sun or Star is between the Zenith and the elevated Pole, substract the Zenith Distance, or Complement of Altitude from the Declination, the Remainder is the Latitude. *Example.*

	D.	M.
If the Declination be —— —— ——	20	00
The Complement of Altitude ——	10	45
The Latitude of the Place is ——	9	15

4. WHEN the Sun or Star is between the elevated Pole and the Horizon, or, which is the same, when the Sun or Star can be seen under the Pole. Add the Altitude of the Sun or Star to the Complement of it's Declination, the Sum is the Latitude of the Place. *Example.*

Sun's

	D.	M.
Sun's Altitude above the Horizon —	5	00
Declination 22° 00′′ it's Complem.	68	00
The Sum is the Latitude ————	73	00

Note, *The Complement of Altitude, which is the Zenith Distance, is what remains, when the Altitude of the Sun or Star is taken from* 90 *Degrees.*

Example.

	D.	M.
From ———— ———— ——	90	00
Substract the Altitude, suppose ——	46	10
Remains the Zenith Distance ——	43	50

CHAP.

CHAP. XXXII.

Of the mutual Situation of Places, and of the making of Globes and Maps.

PROPOSITION I.

Having a given Place on the Earth, to find how another Place bears from it.

THAT is, to find the Point it is in, or the Angle of Poſition made by the Meridian, and an Arch from the one Place to the other: For Example; ſuppoſe we are at *Amſterdam* and deſire to know how *Rome*, *Conſtantinople*, *Stockholm*, &c. lie from it.

The firſt Method.

WHERE you can ſee one Place from another, 'tis eaſily done, by a Semicircle placed horizontally, and directing the Index on it to the Place; then obſerve what Angle that Line makes with the Meridian Line, firſt found; which may be turned to Points, allowing eleven Degrees and a Quarter for a Point; and ſo every Place may be obſerved round you. We may next go to another Place, and from that obſerve, how all the Places in view bear from us; which will determine each Place in a Map, by the cutting of two Lines.

The

The second Method.

IF you have the Places proposed on the Globe, bring the given Place to the Meridian, and elevate the Pole for it's Latitude; and fixing the Quadrant of Altitude in the Zenith, bring it to the several Places successively. The Quadrant will show on the Horizon, the Angle of Position and the Point wanted: thus we may tell how *Rome*, or *Constantinople*, lies from *Amsterdam:* which that we may conceive on the Earth, we must know which way the North lies; and so how the other Points lie.

The third Method.

ON right lined Maps: if the proposed Places be found in them, their Situation towards one another may be seen by the Eye, a right Line being conceived to go thro' the Place, North and South; and another crossing it at the Place at right Angles, shows the East and West: from which the intermediate Points may be conceived. Or by sweeping an Arch, or Quadrant, with the Center at one Place, you'll have their Bearings more exactly. But this holds only in particular Maps; for in general and curve-lined Maps, the Points are not found so exact as one would desire.

The fourth Method.

HAVING the Latitude and Longitude of two Places, their Bearing from the one is accurately found by spherical Trigonometry, either the common way, or by Logarithms, or by an universal Planisphere, or even by the Globe: for in a given Triangle you have the Complement of the Latitude of both Places, and the Difference of their Longitude;

tude; and the Angle wanted is that adjacent to either of the given Sides; which will show how one Place bears from the other. But this will be made plainer by a Master and a Figure, and herein appears the use of the Table of Latitudes and Longitudes.

The fifth Method.

HAVING the Latitude and Distance of two Places, to find their Situation, with respect to one another. This may be done by spherical Triangles; but there is no need of adding more on this Head.

PROPOSITION II.

Having a Place on the Earth, or on the Globe, to find all the Places that lie in the same Point from it.

FOR Example; to find the Places that lie North-East from *Amsterdam.*

ELEVATE the Globe for the Place, bring the Place to the Meridian, there apply and fix the one End of the Quadrant, turn it about to the North-East Point on the Horizon; and you have under the Margin of the Quadrant, the Half of the Places that lie North-East; and the other Half under the Horizon.

DRAW thro' the given Place a great Circle, that shall make the Angle of Position with the Meridian; and the Half of that Circle will go over the Places.

PRO-

PROPOSITION III.

To find all the Places from which a given Place lies in a given Point.

FOR Example; to know all the Places from which *Amsterdam* lies North-West: or to make it more pleasant; having a Place, as *Amsterdam*, to find all the Places from which if I travel to *Amsterdam*, I shall still go North-West. The former Problem might be drawn on a Plane, for the Places sought are all in the Periphery of a Circle, which may be exhibited on a Plane, and are always in one Plane; but the present is a solid Problem, or rather regards the Surface of a solid; for the Places lie not in a Circle, except when the Point is North or South; but in a certain curve Line, which is to be drawn not on a Plane, but on a curve Superficies; and is a curve Line of a particular Kind, terminated on both Sides. And to conceive it, or find the Places in it on the Globe, bring the given Place to the Meridian; and if the Point given be eastward, the Places sought are westward; but contrariwise, if the Point be westward, and the given Place be northerly, the Places lie southerly: but contrariwise, if southerly, and the given Point be due East or West on the Equinoctial, the Places sought will lie in a curve Line, beginning at the given Place and ending in the Pole next to it, and situated on the East Side of the Meridian, if the given Point be the West; but on the West Side if it be East. Thus let the Places sought be those from which *Amsterdam* lies due West; because the vertical Circle of all Places, or the Point due East and West from them, falls on a Point in the Equator, at the Horizon ninety Degrees from the Meridian of every Place; and the Places sought must be on the East Side

Side of the Meridian; so that their prime Vertical running to the West, may cut a Quadrant of the Equator between the West and South: now let great Circles be conceived to pass thro' *Amsterdam* from each Point of that Quadrant, and Meridians drawn from these Points as Poles: the Points in which each great Circle cuts it's Meridian, are the Places sought, which constitute a curve Line running into, and terminating in, the Pole; where there appears to be a Difference between that Line and the Rhumb-Line of a Ship's Course (of which we shall treat in a particular Chapter); for the later is not in Voyages due East and West: but all kinds of the former are such as to be contained between the Quadrants of two Meridians, whose Distance does not exceed ninety Degrees, and end in the Pole.

BUT when any Point is given between the Cardinals; for Example, let the Places be required from which *Amsterdam* lies South-West, or in a Point forty five Degrees from the Meridian of each Place towards the West, remote from the South. First, conceive another Meridian on the East Side of the Meridian of *Amsterdam*, (for 'tis plain the Places sought must be situated there) which makes an Angle of forty five Degrees, with that of *Amsterdam*; this will be the Bounds of the Places sought: nor can any Place be found in any Meridian beyond it, which will answer the Demand. Then imagine a great Circle drawn from *Amsterdam*, that shall be perpendicular to that Meridian; and because the Point given inclines from the West to the South, the Planes sought must be situated in the space of the Triangle, whose Sides are 1. the Perpendicular now drawn. 2. A Part of that Meridian intercepted between the great Circle and the next Pole; and 3. Part of the Meridian of *Amsterdam*, betwixt *Amsterdam* and the nearest Pole.

Holſace, who is not only a Favourer and Promoter of all kinds of Learning, eſpecially Mathematics and Phyſics, but alſo a great Improver thereof: and 'tis for his Honour that I here mention that he ordered a Globe to be made of ſo large a Cavity, that one might commodiouſly ſit in it, and ſee all the fixed Stars on the concave Surface within, marked with a Gold Colour, and the Sun in the Ecliptic, moving by a Skrew; which in the mean time revolved in twenty four Hours, by a ſmall Inſtrument added to it: ſo that the Spectator within had ſuch a View of the Celeſtial Bodies, as we have by Night in the Heavens: and the outward Surface (to come to our purpoſe) had the Places of the Earth on it; ſo that it was both a Celeſtial and Terreſtrial Globe. When we ſay that the Places are to be marked on ſo large a Globe of Braſs, Artificers cannot uſe their way by the Application of paper Maps: nor were it proper to do ſo in making ſuch fine Globes; for the Places muſt be cut out and illuminated, and the Circles and Rivers marked as they are on the Earth; and that by the Table of Latitude and Longitude; uſing alſo a common Globe for giving the Rivers Courſe, and the Bounds of the Sea and Land.

THRO' a given Point, or one taken at pleaſure, let there be drawn a great Circle for the Meridian of the Place; then take therein an Arc from that Point equal to the Latitude of the Place repreſented by that Point, and mark the Limit: then from the ſame Point on the other Side, in the ſame Circle, take an Arc equal to the Complement of the Latitude, or Diſtance of the Place from the Pole; and the Extremity of this Arc will be the North or South Pole, and the other will be in the Parallel of the Place from which on the Meridian ſet the Latitude, which will give the Equator. Then take on the Meridian the other

 Pole,

Pole, and let there be an iron Rod run thro' the two Poles; and on the ends of it let there be a Circle of Brass hung, divided accurately into three hundred and sixty Degrees, or four Quadrants, each Quadrant beginning the first Degree at the Equator, which must be also divided into three hundred and sixty Degrees; and the great Circle drawn on the Globe, may represent the first Meridian: or if you take another, let the Longitude of the place, first set down, be set on the Equator; and at the end of the Arc draw another Circle for the first Meridian, to the West of the former, counting the Pole furthest from you the North; and you will have the East part of the Globe on the right Hand, and the West on the left; and mark the Degrees on the Equator, ten, twenty, thirty to the right Hand, and so round; then taking the Longitude of a Place from the Table, bring the Degree, and Minute if possible, under the brass Meridian, and count the Latitude of the Place North or South; and where it ends mark the Point on the Globe under it for that Place, and so for all other Places

YET this way is not to be wholly followed in Practice; for to make a Globe true, there should first an Axis be run through, the ends of which must be the two Poles, and the first Meridian be first drawn. Tho' 'tis seldom that large Globes are made thus from Tables; but in the common way by Paper Maps, or by taking the Latitudes and Longitudes from lesser Globes, as *Blave* did in the great one sent to the *East-Indies*.

The second Method.

THIS Method is to be used chiefly when a few Places only are to be marked on the Globe, rather than for making a Globe entirely: but it makes

makes uſe of the Diſtances of Places. Let there be an Arc of a great Circle, drawn thro' a Point given; and on it take an Arc from the given Point equal to the Diſtance; the end of that Arc will be the other Place: and to mark a third Place, take with the Compaſſes the two Diſtances of that third Place from the other two, and having, from the two Places as Centers, deſcribed two Arches cutting one another, the Point of Interſection will be the third.

BUT this Method is not proper for the making of the whole Globe, but only when we would mark a few Places on a Globe, which had been omitted; which is eaſily done by the two Diſtances, without the Trouble of calculating their Latitudes and Longitudes. So that the Problem is this, *Having the Diſtance of a Place from two other Places that are found on the Globe, to mark that Place on the Globe.*

The third Method, commonly uſed by Artificers.

THIS third Method of making all the Globes we ſee (excepting the great ones above ſpoken of) both Celeſtial and Terreſtrial, is indeed not very eaſy or quick, if there were only one or a few Globes to be made by it; but is very ready for making ſuch a great Number of them as is ſold, and is thus: Let the Superficies of the Globe and Earth be conceived as divided into twelve Parts or more, if the Globes be large, by Meridians drawn from Pole to Pole; then let there be drawn one of theſe Parts on a Plane, terminated with two Meridians, which will make on the Globe two Semicircles of two Meridians; and a great many Meridians being drawn thro' each Degree on the Equator, and theſe cut by many Portions of Parallels of Latitude thro' the Degrees on the Meridians in

in the form of a Latitude, the middle one will be a Portion of the Equator, and the Meridians are to terminate in the Poles: and taking one for the first Meridian, mark the Degrees of Longitude on the Equator, thirty on the first Part, and from that to sixty on the other Part, and so on; thus you may find the Longitude of any Place, and it's Latitude, meeting in a Meridian and Parallel, cutting one another. And the same way the several Parts of a River or Bay may be marked; and let the same be carved out in Brass or Wood, and by a Rolling-Press some thousands of them may be imprinted on Sheets of Paper; and the Parts cut out and applied to the Globe; so as the Meridian of the one may join that of the other, to make one Meridian on the Globe: and the Meridian need not reach so far as the Pole, but only to the polar Circle; and the Parts about the Poles may be covered with Papers made on purpose for them; for it will be easier to apply them that way, especially if they are large Globes. Thus are all the Places on the Earth exhibited on the Globe; and the brass Meridian, with the Horizon, Standard, Horary-Circle, and Index, are made for the Globe.

THERE are two Things in this Description that require a more full Explanation; the rest I think being easy. 1. How these twelve or twenty four Parts are described on a Plane. And, 2. how plain Papers can be applied to the curve Superficies of a Globe. The first is done easy enough. Thus, for Example, Let the twelfth Part be to be made for the Globe from the Pole to the Equator; find the Periphery of a great Circle for the given Diameter of the Globe by *Archimedes*'s, or any other, Proportion. The Diameter being two Foot, the Length of two Foot marked on the Paper, and each Foot divided into ten Inches, and each Inch into

ten Parts, there will be two hundred Divisions; then As 7 is to 22, So is 200 to 628 $\frac{4}{7}$ or 6 $\frac{28}{100}$ Feet for the whole Periphery. And the fourth Part of it will be 157 $\frac{1}{7}$ hundred Parts. or 1 $\frac{57}{100}$ Feet, and the twelfth Part 52 $\frac{8}{21}$, or half a Foot and $\frac{2}{100}$ and $\frac{8}{21}$ of $\frac{1}{100}$. Then draw a Line on Paper 52 $\frac{8}{21}$ hundred Parts long taken from your divided Scale, in the middle of it, cut it with a Perpendicular 157 $\frac{1}{7}$ hundred Parts long, which will be a Quadrant, and the end of it is the Pole; and divide it into Degrees (the Length of one Degree will be had if 628 $\frac{4}{7}$ be divided by 360) then on the Pole, as a Center, describe Arches thro' each Degree, which will be Parallels; and with the Compasses take off on both Sides of the Meridians, $\frac{1}{24}$ of the Periphery (which will be known by the Proportion of the Parallel to the Equator, as in *Chap.* iv. at the end) and thro' each end draw Lines, and the inclosed Part cut off and applied to the Globe will cover $\frac{1}{12}$ of the Hemisphere. The Application will be easy; if the Part be the $\frac{1}{12}$ Part of the Earth's Superficies, for the Difference between a strait, and curve Line in so small a Part, will not be sensible; and the Paper, being moistened, will stretch a little: and the Places are marked on the Paper before they are applied.

PROPOSITION VI.

To make Geographical Maps.

THE Problem is to be proposed thus, in a Mathematical Style, *Having the Situation of a Plane infinitely extended, to represent thereon the Places of the Earth, according to the Law of Perspective.* Or yet more generally thus:

HAVING a Point given on a Plane which represents some Place of the Earth, to find, on the same Plane,

Plane, other Points and Lines which may represent as commodiously and naturally the Places and Lines of the Earth, or their Situation to the given Place, and among themselves. Thus I think the Sense of the Problem may be better expressed.

BECAUSE few Students of Geography understand the Laws of Perspective, and can have no clear and distinct Knowledge of the Construction of Geographical Maps, nor judge of their goodness and badness, except they know the Elements of Perspective, according to which they are made; therefore a few things are to be here explained in that Art of Perspective.

THE Design of this Art, as every one knows, is to represent visible Objects on a Plane, whose Situation is known, *i. e.* that the parts of the Picture may be so placed as to appear to our Eye the same way as the parts of the Object would appear, if in the same place. And the Method used for it is this:

WHEN they would represent a Point, Superficies, or Body, on a Plane, (whether they see it, or only conceive it) they first suppose it to be seen from some Point. Secondly, they conceive a Plane interposed between the Object and the Eye, in some certain Situation, thro' which, as a transparent Medium, the Objects are seen. Then, thirdly, they suppose Lines or Rays from every point of the Object coming to the Eye thro' that transparent Plane; the several Points of that Plane thro' which the Rays come, being joined together with Lines, will represent the Appearance of the Object to the Eye in that place; which yet (as any one may easily conceive) is not true in all Points according to the Laws of Optics. But because a better Method is not yet found, we must be satisfied with this: for Example, Let the Superficies of the Earth, and all the Points or Circles thereon,

on, be to be repreſented; we firſt conceive the Eye ſituated in ſome Point without the Earth; and a Plane that is tranſparent interpoſed between the Eye and the Earth in any Situation: tho' it is better to ſuppoſe it perpendicular to the Line, from the Earth's Center to the Eye, that the Figure may appear the more regular. Then we are to conceive Lines drawn thro' that Plane, from every Point or the Earth, or of the Circles on it, as the Equator, Tropics, and from all the Cities, Rivers, *&c.* where theſe Lines go thro' the Plane you have the ſeveral Points repreſenting them.

AND becauſe the Earth is round, it's Superficies cannot be all repreſented on one Plane; for two Places of the Earth would thus make two Points on the Plane, which would be confuſed; therefore the one half is to be repreſented in one Plane, and the other in another. And thus the Eye may be ſuppoſed to be within the Earth, as when we would repreſent one Hemiſphere, the Eye may be ſuppoſed in the other, and the Plane between the Eye and the Hemiſphere to be repreſented; and ſo it is if only one Place, as *Europe*, or *Africa*, were to be repreſented, when the Eye may be ſuppoſed in the Earth's Center.

FROM this we think the Reader may underſtand the Nature of the Art of Perſpective; but two things are to be explained, from which the Diverſity of Geographical Maps ariſes.

WE ſaid a Place muſt be ſuppoſed for the Eye; and ſince there are infinite Places in which the Eye may be, the Rays that come from the Object will penetrate the Plane in infinite Places; as a Houſe, it's Walls and Frontiſpiece appear otherwiſe when the Eye is directly oppoſite to it, than when obliquely, and when the Eye is higher than it, than when lower: which Maſters may ſhow to their Scholars by a Figure. Thus the Earth and the

the Circles on it will appear differently to an Eye above the Equator, and to another in it's Axis, or another above a certain Place between the Pole and Equator; which will cause the Circles on the Earth to appear in different Figures; which the Reader may easily conceive, especially if shown by a Master.

ANOTHER thing which we think is to be conceived in this Method, is the Cause of the different bigness of Maps: for all Objects, as Churches or Houses, may be represented either as big or little on the Plane. The Cause of it is twofold; 1. The further the Object is from the Eye, the Appearance is the smaller; the Plane interposed continuing in the same Situation. 2. The nearer the Plane, on which the Representation is made, to the Eye, the Appearance is the less, and the nearer the Object, the greater (*a*).

AND if the Eye be removed never so far from the Object, the Plane being fixed, provided the Eye be moved in a Line thro' the Center, or perpendicular to the Earth's Surface, the Figure will appear the same, tho' lesser (*b*); and so if the Plane be removed

(*a*) That is, if both the Plane and the Eye be together removed from the Object; the Image becomes the smaller, the farther the Eye is removed. But if the Plane retains the same Situation, with respect to the Object, the Image becomes the larger, the farther the Eye is removed. For where the Eye touches the Plane, the whole Projection is confounded in one Point; but as the Eye gradually recedes, the Projection enlarges; and when the Eye is removed to an infinite Distance, the Image becomes as large as the Object.

(*b*) In representing plain Surfaces, how far soever either the Plane, or the Eye be removed, the Figure of the Projection is no way altered, except in it's magnitude; provided the Plane retains it's parallel Situation, and the Eye continues in the same perpendicular Line. And so, if a curve Surface is to be projected, and the Eye have a certain Situation, the Projection remains similar, tho' the Plane be removed to ever so great, or

moved nearer to the Object, or from the Eye, the Image of it in these different Distances will be similar, if the Plane be kept still in a parallel position tho' the Image will be different in it's Magnitude. But if the Table alter it's position, or the Eye go out of the Line that passes thro' the Earth's Center, then the Image will be dissimilar; and the Rays will come thro' Points of the Plane that have a different proportion in their Distances from another.

BUT in projecting all Bodies, and also that of the Superficies of the Earth, they use to place the Plane whereon the Picture is, so as to touch the Body or Superficies in a point, thro' which, if a Line passes from the Eye, it would be perpendicular to the Body, or go to the Earth's Center: but for the Magnitude of the Image we suppose the Eye to be more or less distant from the Earth, which will then appear small.

THESE things, of the Projection of the Earth and the Origin of Maps, being explained, in the general; we shall show the Method itself: where it may be asked, whether the Laws of Perspective must be kept to; the Design of the Maps being to represent clearly and conveniently the places on the Earth in their due Distances; and whether this may be done without Optics: to which I answer, that particular Maps may be made only by the Angles of Position, and the Distances of places; but in large Maps there must be an exact Observation of the Laws of Perspective; even tho' the

or ever so small a Distance. But if the Eye be moved, tho' in the same perpendicular Line the Figure immediately alters, even tho' the Plane remains fixed. Hence there is a very different Appearance in the thirty fifth and thirty eighth Figures, proceeding solely from this, that in the former the Eye is supposed removed only a Semidiameter of the Earth from the Center; and in the latter, placed at an infinite Distance.

Places

Places of the Earth are not truly represented as they are on the Earth. For we must know, that there is a three-fold end for which Maps are made; 1. That all Places may have such a Situation and Distance from the chief Circles of the Earth; as the Equator, Parallels, Meridians, as on the Earth itself, that the Distance of the Parallel of each Place from the Equator, the Zone, the Climate, *&c.* may be seen in the Maps: for the Properties and Celestial Appearances in the Countries depend on it. 2. That the bigness of each Country may be in the same in Porportion as they are on the Earth. 3. That Places may be so situated, and distant from one another as they are on the Earth.

The first of these should be exactly answered by the Maps; and they do it for the most part; being made from Tables of Latitude and Longitude: nor is it hindred by the Laws of Perspective. But the second cannot be accurately done if the Laws of Perspective be observed; for the Parts of the curve Superficies that are furthest from the Eye, appear less than those on the Plane near the Eye; yet the inequality is but small if the Eye be supposed to be at an infinite Distance from the Earth *(c)*. The third Requisite; no large

(*c*) It is a common and unavoidable Error in all the Projections of this kind, that the Parts unequally distant from the Center, are represented as unequally distant in the Map: whence the Magnitudes and Figures of the Parts of the Earth, are more or less altered, and distorted, according to the different Position of the Eye. To understand how this happens; and how far it may be corrected; 'twill be proper to consider the Formation and Origin of these Representations. And this will be the easier, if we drop the Description of the Globe: and make choice, of any single Circle, by way of Example.

Suppose, therefore, half the Circle CBCD were to be projected, *viz.* CBC: (*Fig.* 34. 35. 36. 37.) the Eye being placed in O, in the Diameter

large Maps, ſuch as thoſe of the Earth, or the four Quarters thereof, can ſupply; tho' in ſmall Parts they

meter BED, drawn out to any length towards D, and the Eye directed upon the right Line CEC; it appears that if any Difference be found in the Projections of the different Parts, it will be the greateſt betwixt the Repreſentations of the Parts in the middle of the Semicircle, lying near B, directly under the Eye; and thoſe which lie fartheſt removed from the former; *viz.* in C *c*. Theſe Parts, therefore, we are chiefly to conſider.

Suppoſe then B *b* to be an infinitely little Part of the Periphery; ſo as to paſs for a right Line; and C *c*, a Part equal to it; and the Eye at pleaſure, ſituated in the right Line E D, infinitely produced: then the Repreſentation of B *b*, will be the little Line E *e*, and the Repreſentation of C *c*, will be C *d*.

Now, from the Elements of Geometry, becauſe the Triangles O B *b* and O E *e*, are ſimilar, O B : O E : : B *b* : E *e*. And again, becauſe the Triangles O E *d* and *c* C *d* are ſimilar, O E : E *d* : : *c* C : C *d*. Whence we may eaſily underſtand what the Proportion will be betwixt E *e* and C *d*, the Projections of the little Lines B *b* and C *c* at whatever Diſtance the Eye be placed.

For, firſt, if the Eye were removed from the Center E, (*Fig.* 34.) by the infinitely little Diſtance O E; then E *e* will be infinitely little in reſpect of B *b*, or C *c*, and therefore more than infinitely little with reſpect to the Line C *d*; which in this Caſe is equal to half the Radius.

Secondy, if the Eye be in the Point D; (*Fig.* 35.) then E *e* will be half the Line C *d*: as in the firſt, ſecond, and eighth Method of the Author, wherein the Parts directly expoſed to the Eye, are repreſented much ſmaller than thoſe placed at the Extremities of the Map. *See Fig.* 39, 40, and 45.

But if O D be the Side of a Decagon, inſcribed in a Circle; the Projections of the Parts B *b*, and C *c*, will be equal to E *e*, and C *d* (*Fig.* 36).

If the Eye (*Fig.* 37) be removed to an infinite Diſtance, as in the Author's ſeventh Method; then E *e*, will be infinitely bigger than C *d*. And hence, in (*Fig.* 43), the Projections of the Parts that fall in the middle of the Map, are much larger, than of thoſe which approach to the exterior Circle.

When the Eye is placed in any intermediate Part betwixt thoſe above-mentioned; the Lines E *e* and C *d*, will be proportionable to each other, in an intermediate Manner, reſpectively. So that we may make the Repreſentations of the Parts B *b*, and C *e*, either equal, or in any Proportion, greater than each other, by chuſing a proper or correſponding Place for the Eye.

Among

they do it indifferently well, and most People think 'tis done in great Maps too; but we shall explain these things more fully in the Description itself; only we would here observe, that in all the general Maps commonly sold by Artificers, that Point is supposed to be just under the Eye in the Projection, which is in the middle of the Map; for

Among the infinite Positions assignable to the Eye, there are chiefly two that have been used, wherein it is placed either in the Point D, or removed to an infinite Distance; because no Method was found more easy in Description, or more commodious with respect to the Error abovementioned. And hence the Surface of the Earth has been represented in a very distorted and deformed Manner; whilst those Parts that fall chiefly in the middle or extremities of the Map, were exhibited either much larger, or much smaller than they ought to have been.

This being observed by that excellent Astronomer, M. *de la Hire* *; he invented a Remedy for the inconvenience, by making the Distance D O, (*Fig.* 38.) equal to F G, the right Sine of forty five Degrees. And hence the right Line O G, being drawn, bisecting the Quadrant B C, it also bisects the Radius E C, which represents that Quadrant; as easily appears by considering the similar Triangles OFG, and OEI. And thus the other Parts of the Quadrant B C, and, in the like manner, of the whole Semicircle A B C, are represented in the Projection, nearly proportional to each other, and to Sense, perfectly so.

And as this Method of describing the Earth or Heavens, is not inferior to the former Methods, in Point of facility; so it is highly preferable in respect of accuracy and similiarity.

In this Projection, all the Circles passing thro' the Points B and D, and directly exposed to the Eye, are represented by right Lines; and all those which have their Planes parallel to the Plane of the Map AEC, or stand perpendicular to the Diameter BD also denote Circles in the Map; but the rest are elliptical; all which, whether strait Lines, or the Diameter of Circles, and Ellipses, are found in the same manner, as is described by the Author. We must however observe, that the Lines for dividing the Diameters A C, and B D, which, in *Fig.* 39 and 40, are drawn from the ends of the Diameters, are to be drawn for the Points that lie removed from those ends by the interval of D O.

* *Hist. Acad. Scient.* 1701.

above

above that the Eye is ſuppoſed to be; and 'tis ſo in many particular Maps, but not all.

IT will be of uſe to underſtand what follows, if Maſters and Scholars purchaſe ſets of Maps; that what we ſay may be illuſtrated by Examples.

The firſt eaſy Method, in which the Eye is placed in the Axis

1. I will ſhow the Conſtruction of the North Hemiſphere this way. Let us ſuppoſe the Eye placed without the Hemiſphere, and to be above the North Pole; and thus the Eye will be in the Earth's Axis, 'tis no matter whether in the Axis produced from the Pole, or in the Axis near the South Pole. For the Map or Plane on which the Repreſentation is to be made, we may take the Plane of the Equator, or one touching at the North Pole, if the Eye be ſuppoſed to be in the Axis produced from the North Pole. But that we may the better expreſs it without Confuſion, let us ſuppoſe the Eye at the South Pole, and the Plane of the Equator to be the Map or Plane on which the Projection is to be made (the Earth being conceived to be ſmall), and we are to ſuppoſe Rays from all Parts of the North Hemiſphere coming to the Eye, which will all penetrate the Plane of the Equator; the Points where they penetrate will repreſent the Places they come from; and all the Points in the Circles, parallel to the Equator, will appear as a Circle, and therefore the Equator will be the primitive Circle and Bounds of the Projection; and the Pole will be in the Center, the Diameters will be the Meridians, and the Parallels of Latitude will have the ſame Center with the Equator, *viz.* the Pole: and each Place will be where it's Meridian cuts it's Parallel of Latitude. The other Circles or Semicircles will not be

be Circles in the Figure, but Ellipses; for Example, the Horizon and vertical Circles will be of an elliptical Figure, as made by a subcontrary Section of the Cone (as they who understand Conic Sections are sensible).

AND to understand this the better, we must conceive a Cone of Rays, whose Vertex, or Top, is the Eye, and the Base a Circle on the Earth to be represented; the Sides being the Rays from the Eye to the Periphery, and that this Cone is cut by a Plane several ways according to it's Position; which will cause a Projection of the several Circles on the Earth. Thus the Ecliptic, only whose half is represented in the northern Hemisphere, makes an Ellipsis, or a part of it; yet properly it represents not the Ecliptic on the Earth which is changed every Day, but only the Ecliptic for one Day, or one Moment of a Day; and it's Intersection with the Equator may be at any Point: yet in all Maps 'tis thought most commodious to be where the first Meridian cuts the Equator.

THUS we have explained the Origin and first Method of those Maps that suppose the Eye to be in the Axis; and how 'tis to be done we shall now show.

ON Paper, or a Plane: Let a Point be taken for the Pole, (*Fig.* 39.) and on it, as a Center, describe a Circle great or small, according as you would have the Projection, and that will be the Equator; these two are taken at Pleasure, but the rest must be found from these. Divide the Equator into three hundred and sixty Parts, and Lines drawn from the Center to these Parts will be Meridians; counting that the first which goes thro' *o o*. Then the Parallels of Latitude are to be described. Let the four Quadrants of the Equator be marked A B from 00 to 90, and B C from 90 to 180, and C D from 180 to 270, and D A from 270 to 00 again; and taking one Quadrant, as B C from each

above that the Eye is ſuppoſed to be; and 'tis ſo in many particular Maps, but not all.

IT will be of uſe to underſtand what follows, if Maſters and Scholars purchaſe ſets of Maps; that what we ſay may be illuſtrated by Examples.

The firſt eaſy Method, in which the Eye is placed in the Axis

1. I will ſhow the Conſtruction of the North Hemiſphere this way. Let us ſuppoſe the Eye placed without the Hemiſphere, and to be above the North Pole; and thus the Eye will be in the Earth's Axis, 'tis no matter whether in the Axis produced from the Pole, or in the Axis near the South Pole. For the Map or Plane on which the Repreſentation is to be made, we may take the Plane of the Equator, or one touching at the North Pole, if the Eye be ſuppoſed to be in the Axis produced from the North Pole. But that we may the better expreſs it without Confuſion, let us ſuppoſe the Eye at the South Pole, and the Plane of the Equator to be the Map or Plane on which the Projection is to be made (the Earth being conceived to be ſmall), and we are to ſuppoſe Rays from all Parts of the North Hemiſphere coming to the Eye, which will all penetrate the Plane of the Equator; the Points where they penetrate will repreſent the Places they come from; and all the Points in the Circles, parallel to the Equator, will appear as a Circle, and therefore the Equator will be the primitive Circle and Bounds of the Projection; and the Pole will be in the Center, the Diameters will be the Meridians, and the Parallels of Latitude will have the ſame Center with the Equator, *viz.* the Pole: and each Place will be where it's Meridian cuts it's Parallel of Latitude. The other Circles or Semicircles will not be

be Circles in the Figure, but Ellipses; for Example, the Horizon and vertical Circles will be of an elliptical Figure, as made by a subcontrary Section of the Cone (as they who understand Conic Sections are sensible).

AND to understand this the better, we must conceive a Cone of Rays, whose Vertex, or Top, is the Eye, and the Base a Circle on the Earth to be represented; the Sides being the Rays from the Eye to the Periphery, and that this Cone is cut by a Plane several ways according to it's Position; which will cause a Projection of the several Circles on the Earth. Thus the Ecliptic, only whose half is represented in the northern Hemisphere, makes an Ellipsis, or a part of it; yet properly it represents not the Ecliptic on the Earth which is changed every Day, but only the Ecliptic for one Day, or one Moment of a Day; and it's Intersection with the Equator may be at any Point: yet in all Maps 'tis thought most commodious to be where the first Meridian cuts the Equator.

THUS we have explained the Origin and first Method of those Maps that suppose the Eye to be in the Axis; and how 'tis to be done we shall now show.

ON Paper, or a Plane: Let a Point be taken for the Pole, (*Fig.* 39.) and on it, as a Center, describe a Circle great or small, according as you would have the Projection, and that will be the Equator; these two are taken at Pleasure, but the rest must be found from these. Divide the Equator into three hundred and sixty Parts, and Lines drawn from the Center to these Parts will be Meridians; counting that the first which goes thro' *o o*. Then the Parallels of Latitude are to be described. Let the four Quadrants of the Equator be marked AB from 00 to 90, and BC from 90 to 180, and CD from 180 to 270, and DA from 270 to 00 again; and taking one Quadrant, as BC from each

of whose Degrees draw occult Lines to D (and mark those that go thro' the 23 *degr.* 30 *min.* and 65 *deg.* 30 *min.*) the Line D B is as far from P as the Eye is from the Pole: and thro' P, as a Center, draw Circles thro' every Point of Intersection in the Line P C, which will be Parallels of Latitudes which may be counted on the Lines A P and C P 1, 2, 3, 4 from the Equator to the Pole; and you will see the Latitude of each, and mark thereon the Tropic of *Cancer*, and the polar Circle at 23 *deg.* 30 *min.* and 66 *degr.* 30 *min.* there need only be coloured Lines at every fifth Meridian; the rest being occult, that there may be room for affixing the Names of Places.

AFTER the Parallels and Meridians are drawn it will be easy to mark down the Places from the Tables of Latitude and Longitude; finding first their Longitude, and then the Parallel of their Latitude; and where these two cut one another is the Place.

IF the Ecliptic is also to be drawn, it must be done before the Names of Places are written; and it being an Ellipsis in the Projection, the several Points are to be found thro' which it passeth; the first Point is where the first Meridian cuts the Equator, *viz.* at the first of *Aries*, and the other Point in the opposite Part of the Equator, which will be the first of *Libra*; and the intermediate Point is where the Meridian thro' ninety Degrees cuts the Tropic. Thus we have the three Points thro' which a Portion of the Ellipsis passes, which will be less than the half of an Ellipsis, for the other Points, as the first of *Taurus*, *&c.* there the Declination of these Points, and their right Ascensions from the first Meridian must be taken from the Tables here adjoined.

Declina-

Declination			*Right*	*Ascension.*	
D.	*D.*	*M.*	*D.*	*M.*	
15 of *Aries* and *Virgo*	5	56	13	48	166 for 15th of *Virgo*
1 of *Taurus* and *Virgo*	11	31	27		152 1st of *Virgo* begins
15 of *Taurus* and *Leo*	16	24	42		137 for 15th of *Leo*
1 of *Gemini* and *Leo*	20	13	57		122 1st of *Leo* begins
15 of *Gemini* and *Cancer*	22	41	73		106 for 15th of *Cancer*.

THEN where 13 or 14 Degrees cuts the Parallel of 5 Degrees, or rather 6 Degrees, that Point will be the fifteenth of *Aries*; and where 27 cuts the Parallel of $11\frac{1}{2}$, there begins the first of *Taurus*; and where 42 cuts the Parallel of 16, there is the fifteenth of *Taurus*; and where the Meridian 106 cuts the Parallel 22 *D.* 41 *M.* there begins the fifteenth of *Cancer*; and where the Meridian 122 cuts the Parallel of 20, there the first of *Leo* begins; and so for the rest: these Points being joined by a curve Line, we shall have a Portion of the Ellipsis for the North Part of the Ecliptic, whose Signs are easily marked, taking the end of each Sign in the Tables to which you have it's Declination and Right Ascension, as we marked, 15 Degrees of *Taurus*; the first of *Cancer*, &c. Thus is the Map finished, that represents the northern Hemisphere.

'TIS plain from the Description and Construction, that the Method is easy and pleasant; now for the Use and Advantage thereof. We said there is a three-fold end in constructing Maps; the first of them is answered because the Latitude and Longitude of Places are thus shown accurately: it shows also the Zones, or the Distance of Places from the Sun's Way. As for the second, *viz.* the proportionate bigness of each Country; that is not so truly shown; for the nearer the Places are to the Equator, they are proportionably larger; yet the Difference is but small, because of the great Distance the Eye is supposed to be at from them; and that fault is com-

penſed by marking down the better the Places near the Equator, thoſe near the Pole being not much inhabited. As for the third end, *viz.* the Situation of Places, and their Diſtance, this cannot be known by theſe Maps; for the Lines on the Maps which denote theſe, are otherwiſe than they are on the earth; but to know the Situation of Places with reſpect to any other, the Horizon of that place muſt be drawn, as an Ellipſis, thus. Let there be counted from the Meridian of the Place ninety Degrees both ways, and the riſing and continuance of the Sun above the Horizon may be known from that part of the Map which begins and ends at the two Points where the Horizon cuts the Equator; and the middle Point will be in the other Quadrant of the Meridian; as far from the Equator as the Plac is from the Pole: which will ſhow the North Point. The South Point we ſhall ſhow how to find a little below, if more than a Hemiſphere be ſhown in the Map, it not being in an Hemiſphere only, except the Horizon of the Pole, which is the Equator. Thus then we have three Points for the Horizon; the other Points may be found eaſier by the Globe, thus: Elevate it for the Latitude of the Place, and take the Point in each Parallel thro' which the firſt Meridian paſſes, and bring it to the Horizon, and mark the Degrees under the Meridian, and do ſo for each Point in the firſt Meridian, and then count the Degrees for each Parallel from the Meridian of the Place on the Equator both ways; and where the Meridian cuts the Parallels anſwering them, you have the other Points thro' which the Horizon is to be drawn, by which you may judge nearly the Situation of other Places from the Place given.

THUS may almoſt the whole Earth be drawn in one Map, if either Pole, for inſtance, the South Pole, be taken for the Place of the eye: and the primitive

 Circle

Circle inclosing the Map, may be any Parallel; for Example, if you take the antarctic Circle, if you would represent the Superficies between the North Pole and it in the Map, it wants only the lengthening out of the Meridian Lines in the former Construction, and Parallels drawn on the other Side of the Equator, and let the Ecliptic be drawn entire, and the Horizon if you please compleated.

BUT because the Parts, or Degrees, near the South Pole will be thus much larger than near the Equator, or in it, which is against the Truth of the Thing, 'tis better to divide the Map into two; one showing the North; the other the South Hemisphere.

THERE are few Maps drawn this way, tho' there are commonly two small ones of this kind added to the general right lined Maps, one representing the Countries about the North, the other about the South Pole; which Readers may see for the better understanding what is said here: but these things are better understood from seeing them done than by Words.

The second Method; the Eye being in the Plane of the Equator.

THE preceding Method of describing Geographical Maps, neither shows the Magnitude and Situation of Places, nor is it fit to describe an Hemisphere, with Poles in it, and so represent all Places in one Semicircle of the Meridian; and besides, 'tis not agreeable to our way of thinking, to have the Pole in the Center, which makes it more difficult to conceive the Map, and therefore another Method was found out; which is indeed more difficult than the former, but more fit to represent Places: and it also removes the Poles from the Equator.

TO underſtand this Method we muſt conceive the Earth's Surface divided into two Hemiſpheres, by an entire Circle of the firſt Meridian, and are to be exhibited in two Maps.

THE Eye is ſuppoſed in a Place of the Equator, ninety Degrees from the firſt Meridian; the Map in which it is repreſented is the Plane of the firſt Meridian; and the Hemiſphere, which lies under that, in reſpect of the Eye above it, is that which we would repreſent on the Plane. In which Projection the Equator becomes a ſtrait Line, and that Meridian ninety Degrees from the firſt, becomes alſo a ſtrait Line, the other Meridians, and all the Parallels of Latitude, and the Ecliptic become Circles, becauſe their Cones are cut by the Plane, or Map, in a ſubcontrary Section; the explication of which depends on the Doctrine of Conic Sections; and is underſtood better by Sight than by Words.

THE Deſcription is made thus: Having taken in the Map the Point E (*Fig.* 40) for a Center, deſcribe a large or ſmall Circle ABCD, as you would have your Map large or ſmall. This repreſents the firſt Meridian, and it's oppoſite; the Diameter BD repreſents the Meridian that is ninety Degrees from the firſt, and B the one Pole, and D the other; and AC perpendicular to AD is the Equator; Let each Quadrant AB, BC, CD, DA, be divided into ninety Degrees. And to repreſent the Meridians and Parallels, or to find the Arches of the Meridians and Parallels, this muſt be done.

1. LET the Equator AC be divided into one hundred and eighty Degrees, for it repreſents only the half of the Equator, or AE, EC in ninety Degrees each: from the Point D draw ſtrait Lines to every Degree of the two Quadrants ABC, or apply a Ruler to D, and to each Degree in the Semicircle

micircle ABC, and it will divide it into one hundred and eighty Parts, which are Degrees of Longitude, to be marked 1, 2, 3, 4, from the first Meridian. Thro' each Point, and the two Pole Circles are to be described, which will be Meridians; but how a Circle is to be described thro' the three Points B1D, or B2D, *&c.* is to be learnt from Geometry: and that is by finding the Centers of each Circle, which will be all in the Equator, as the Meridian DAB hath E for it's Center. *Euclid* shows a Method, in *Book* iv. *Prop.* iii. by connecting the Lines B1, B2, *&c.* and bisecting them by Perpendiculars which will cut one another in the Equator, which, if need be, must be drawn out; but it will be easier in Practice, to draw Lines from B, thro' each Degree of the Semicircle, ABC to the Equator protracted, which will give the Points *a*, *b*, *c*, *d*, *e*, and so 1 *a* will be the Diameter of that Meridian, which should pass thro' 1; and 2 *b*, of that thro' 2, *&c.* if then 1 *a*, and 2 *b*, *&c.* be bisected, we shall have the Centers of the Meridians to be described.

YET the Work will be easier, and less liable to Error, especially in great Maps, by the Canon of Tangents; for thus there shall be no need of drawing Lines; for to divide EA, EC, *&c.* into Degrees we do thus: We divide, or suppose to be divided, EB, by a proper Scale, into ten thousand Parts, and from the Canon we take the Tangent of thirty Minutes, sixty Minutes, and one Degree and a half, *&c.* and each of those Tangents taken from the Scale, we lay down on EA, EC, EB, ED, and the nearest Points will contain one Degree to be counted as before. Then to find the Centers of each Meridian, take any Number between BC or E and any Degree, and the Double thereof take from ninety, or the Number itself from it's Complement; and taking the Tangent of the Remainder from the Canon, and set from E on

EC or EA, and it will give the Center of the Meridian to be described thro' that Degree, and so for all other Meridians. Practice will make this easy. The Foundation of the Work of finding the Centers is a Theorem in Trigonometry; *viz. The Difference of the Tangents of two Arches that constitute a Quadrant, is double to the Tangent of the Difference of the Arches.*

TO draw the Parallels; the Meridian DB is to be divided the same way, into one hundred and eighty Degrees, as EA, EC were; *viz.* by drawing from C to each Degree of the Periphery DAB, occult Lines; tho' the Parts of EA may be transferred to EB, the Points or Degrees from E to B, that is from the Equator to the Pole, or from E to D, the other Pole, are to be counted 1, 2, 3, 4, &c.

THEN thro' each of these Parts, and the corresponding Degrees on the Quadrants, are the Arches of the Parallels to be drawn on both Sides of the Equator. And thus we shall have the Tropics thro' twenty three Degrees thirty Minutes; and the polar Circles thro' sixty six Degrees thirty Minutes.

TO draw the Ecliptic there are two ways; for either the Ecliptic is supposed to cut the Equator in the Center, and then it will be a strait Line, and is to be divided the same way as the Equator; but if it be drawn so as that the Point of Intersection, or the first of *Aries*, shall be in the first Meridian; then it will be the Part of a Circle, of which the two Points will be A and C, and the third the Point where the Meridian of ninety cuts the Tropics: and thus 'tis commonly drawn, because thus 'tis always in both Hemispheres.

AND to determine the Places in those Maps, their Latitudes and Longitudes are to be taken out of Tables; and where their Meridian cuts their Parallel, this is their Place.

BY

BY the like Method the whole Superficies of the Earth may be drawn in one Map, if we take not the Planes of a Meridian for the Map; but another that ſhall be parallel to it, and very near the Eye: and thus the whole Parallels, and the Meridian with it's oppoſite, may be drawn. But yet the Appearance will differ much from the thing itſelf on the Earth; and therefore is not practiſed by Artificers, who rather draw two Hemiſpheres in one Map; yet it will be uſeful for Students to exerciſe themſelves in ſuch Things: and it will be beſt to place the Eye in the firſt Meridian at A; thus BD will be the firſt; and the Equator will not be AC, but a Line parallel to it, thro' a Point in ED, which is divided into as many Degrees as there are in the Arch cut off.

A ſecond Advantage is, that it aptly repreſents the Hemiſphere between the two Poles.

A third is, that it nearly ſhows the Latitudes and Longitudes of each Place; as they are on the Earth.

THE Diſadvantages are firſt, that the Degrees of the Equator are divided unequally; being larger the nearer to the firſt Meridian, or it's oppoſite; and therefore the Countries that are equal on the Earth will appear here unequally, as in the preceding Method; but this defect is in part remedied if the Eye be ſuppoſed far from the Earth: and the ſame way do the Places about the Poles ſeem larger than they ſhould do. 2. The Situation of Places is not eaſily found, nor the Diſtance of two Places.

The

The third, fourth, and fifth Method for right-lined Maps.

THERE are to be ſold univerſal Geographical Maps, that have all ſtrait Lines, both for the Parallels and Meridians: which is impoſſible by the Law of Perſpective: nor is it poſſible that the Eye and the Plane can be ſo ſituated, that both the Parallels and Meridians will appear as ſtrait Lines. In the firſt Method the Meridians were ſtrait Lines according to Perſpective; and the Parallels are Circles: and in the fifth Method following, the Circles of Latitude will be ſtrait Lines, and the Meridians Ellipſes. In other Methods, by the Law of Perſpective, both are curve Lines, excepting one wherein the Meridians are ſtrait Lines; but the Circles of Latitude are Hyperbola's; that is, when the Eye is placed in the Centre of the Earth, and ſeeth the Hemiſphere on both Sides of the firſt Meridian, and the Plane thro' which the Eye looks, is parallel to the firſt Meridian; thus the Meridians will be ſtrait Lines, and the Circles of Latitude Hyperbola's. The Diviſion of the Equator and Meridians according to this Method being eaſy, they that delight in a Variety of ſuch things may draw ſuch a Map, tho' the Hyperbola's will not be ſo eaſily drawn as the other Parts; therefore we ſhall ſay no more of it: they who would try it may conſult a Maſter. The right lined Maps then are not according to the Laws of Perſpective, but rather againſt them: and they are of two Sorts, ſome have both the Degrees of Latitude and Longitude equal, as they were of old; others now have the Degrees of the Equator equal (contrary to the Law of Perſpective) but not of the Meridians: for the Degrees on them become ſtill bigger the nearer either Pole; ſo that the eighth Degree is ten Times larger

larger than the firſt at the Equator (and at the Pole they are infinite which cannot be expreſſed in any Map); whereas the Law of Perſpective admits only of a threefold encreaſe there (*d*).

THE right-lined Maps, according to the firſt Way are very eaſy; for having taken A B (*Fig.* 41.) for the Length of the Map, 'tis divided into one hundred and eighty Degrees, or equal Parts, for one Hemiſphere; and thro' each Degree are drawn Meridians, ſtrait and perpendicular; and on theſe are taken Parts equal to thoſe on the Equator; and thro' each Degree of Latitude are drawn Parallels to the Equator, or Circles of Latitude; and thus may each Place be marked, as before, by it's Latitude and Longitude.

THE ſecond Method agrees with the firſt in the equal Diviſions of the Equator, thro' which Perpendiculars are drawn, which will be Circles of Longitude; (*Fig.* 42.) but for drawing Parallels to the Equator, there is another Method: for the Meridians have the Degrees on them greater, nearer the Pole. And this happens becauſe other Maps do not ſhow the Diſtance, nor poſition of two Places, both which may be had here: for becauſe the Meridians of each Degree are equidiſtant, or parallel, therefore the Places are thereby removed from the firſt Meridian, more than they ought to be; and the more the nearer the Pole, in proportion as the whole Sine exceeds the Sine of the Complement of the Latitude of the Place; for As Radius to the Sine-Complement of the Latitude of

(*d*) The Laws of Perſpective do not indeed regard the Increaſes of the Meridians, in this kind of Maps, but obſerve a different Proportion, as the Makers of theſe Maps allow. But that the Degrees ſhould increaſe ſo largely near the Pole, is not contrary to the Laws of Perſpective; which affords not only a tripple, but any other Degree of Increaſe, as appears from the Note immediately preceding.

the

the Place, So is a Degree on the Equator, or any Number of them, to the ſame Number on the Parallel; and therefore they muſt be leſs there than on the Equator, and the leſs the nearer the Pole: but in right-lined Maps they are drawn equal in all the Parallels. And as Degrees on the Circles of Latitude increaſe more than they ſhould, thoſe of the Meridians are made to increaſe as much; that the one may correct the other; for as the quantity of one Degree in each Parallel is to a Degree on the Equator, ſo is the Sine-Complement of the Latitude of that Parallel where the Degree begins to the whole Sine: and ſo is a Degree of Latitude on the Equator to a Degree of Latitude through whoſe beginning the Parallel paſſeth. But more accurately thus: by taking the Sine-Complement of the Latitude which begins the Degree, and adding it to the Sine of the Complement of Latitude that ends the Degree; and taking the one half of both for the firſt Term in the Proportion.

For Example.

LET the quantity of the firſt Degree of Latitude be to be determined, the Degree on the Equator being ten Parts; by the firſt Proportion it will be equal to that on the Equator, becauſe the Degree begins at the Equator; but by the ſecond Proportion I take the Sine-Complement of 0 Degrees (which is the Sine of 90) 100000, which I add to the Sine-Complement of 1 Degree, or the Sine of 89 Degrees, which is 99985, and they make 199985, whoſe half is 99992; then As 99992 is to 100000, So is 10 to $\frac{80}{1000000}$; for the firſt Degree which increaſes ſo little above 1 Degree on the Equator, that it cannot be marked on the Map; ſo we may count them equal: but they increaſe ſenſibly as they approach to the Poles. Let the

the 60 Degree be to be marked by the first Proportion, the Sine-Complement of 59 is 51503; then As 51503 is to 100000, So is 10 to $19\frac{2}{5}$ to be taken from the same Scale where the Degree is made ten Parts. By the second Proportion the Sine-Complement of 59 is 51503, and the Sine-Complement of 60 is 50000, their Sum 50751; then As 50751 is to 100000, So is 10 to $19\frac{3}{5}$; which is but a little above the former, and not worth the Pains to observe; and when the bigness of the second Degree is found, 'tis thus to be added to the first; and the quantity of the third Degree is to be added to them. To make the Thing more easy, we here add a Table of the Magnitude of each Degree; the Degree on the Equator being 100.

End of Degr.		*End of Degr.*		*End of Degr.*	
1	100	17	1725	33	3499
2	200	18	1830	34	3619
3	300	19	1936	35	3740
4	$400\frac{1}{3}$	20	2042	36	3863
5	$500\frac{2}{3}$	21	2150	37	3988
6	601	22	2256	38	4114
7	702	23	2364	39	4241
8	802	24	2473	40	4371
9	903	25	2583	41	4502
10	1005	26	2694	42	4636
11	1107	27	2806	43	4772
12	1209	28	2918	44	4909
13	1311	29	3032	45	5053
14	1414	30	3147	46	5193
15	1517	31	3263	47	5338
16	1621	32	3347	48	5486

End

End of Degr.		*End of Degr.*		*End of Degr.*	
49	5637	61	7749	73	10900
50	5791	62	7960	74	11243
51	5981	63	8175	75	11617
52	6109	64	8399	76	12017
53	6274	65	8631	77	12445
54	6441	66	8872	78	12908
55	6611	67	9023	79	13409
56	6790	68	9384	80	13960
57	6970	69	9691	81	14565
58	7157	70	9943	82	15243
59	7349	71	10243	83	16009
60	7546	72	10558		

THE Degrees of Latitude being thus marked on the Meridian, draw Parallels thro' the end of each Degree; and each Place is to be marked where it's Circle of Latitude and Longitude interſect each other.

BUT the Countries near the Pole are ſtretched too much northwards; and therefore the Places between the Pole and the polar Circles uſed to be ſet down in two Maps, by the firſt Method and joined to the univerſal Map.

THE Uſe of ſuch Maps is, (1.) to find the Latitude and Longitude of Places, as before. (2.) Having, in *Fig.* 42, the Place R, from which I ſail, and the Place S, to which; to find the Point I muſt ſteer my Courſe to; I draw a Parallel thro' R, which, with R S, ſhows the Angle or Point I muſt ſteer to. Seamen uſe another way. (3). The Diſtance between two Places may be found, if I take their Diſtance with the Compaſſes, and ſet it on the Meridian, ſo as the Feet of the Compaſſes may be equally diſtant from the Parallel in the middle

middle between these two Places: but this is not very accurate.

The sixth and seventh Method.

PTOLEMY, in the latter Part of the last Chapter of his first Book of Geography, proposes another Method, and shows how to represent thereby the then known Part of the Earth. In this Method both the Equator and Circles of Latitude are also Arches of Circles; and the Meridians, Arches of an Ellipsis. The Eye is supposed to be above the Meridian, which is in the middle of the Earth inhabited, and in the middle between the greatest and least Latitude known; but because of the trouble of drawing an Ellipsis, and because it seems to be designed by *Ptolemy* to represent the Part of the Earth inhabited, 'tis not used by Artificers. And the Method of representing the Circles of Latitude by strait Lines, but the Meridians as halves of Ellipses, is something like this; which Projection is made by supposing strait Lines to fall perpendicularly from every Point of one Hemisphere, on the Plane of the first Meridian Circle; and the Eye at an infinite Distance: as those skilled in Dialling say, that all the Rays from the Sun, or any Part of it, come so near Parallels as to be accounted such, and cause the same Shadow as if they were parallel: which is not very difficult to conceive.

IF therefore you would represent an Hemisphere of the Earth after this manner, chuse a Point on the Plane as E, (*Fig.* 43.) and from that, as a Center, describe a Periphery ABCD, the Quadrants being AB, BC, CD, DA, divide each into ninety Degrees, beginning from AC to B and D, and BAD will be the first Meridian, BCD it's opposite, and the middle one BD will

be ninety Degrees from the firſt BAD. Then draw AC, which will be half of the Equator, and draw Parallels thro' every Degree of the Quadrants, in which you will have the Tropics at twenty three Degrees thirty Minutes, and the polar Circles at ſixty ſix Degrees thirty Minutes. The Parts into which EB, ED are divided, are Degrees of the Meridian BD, which are to be marked 1, 2, 3, *&c.* and the ſame Parts muſt be taken in the Quadrant of the Equator EA, and the other EC, and marked 1, 2, 3, to 180, beginning at the firſt Meridian BAD. And thus the Parts in EA, EC will have the Parts into which the Equator is divided, and are Degrees of Longitude, thro' which, and the Poles, Meridians are to be drawn as half Ellipſes; and becauſe BD is the longeſt Diameter, and the ſhorteſt is different in each Ellipſis, and will be between E and the Degree of Longitude; it will be eaſy to draw them with an Inſtrument now common, having their longeſt and ſhorteſt Diameter. The ſeveral Points in the Ellipſis may be found, which may be joined by a good Hand; but 'tis better to draw them with a thin Piece of Whalebone or Steel.

HAVING thus drawn the Circles of Latitude, and the Meridians, all Places may be laid down according to the Points in which their Circles of Latitude and their Meridians interſect. In which Map the Ecliptic will be either a ſtrait Line, or a curve (as was ſhown in the Maps by the ſecond Method) and may be eaſily drawn.

THESE kind of Maps are as good as the former; and have this Advantage, that they repreſent plainly the decreaſing of the Circles of Latitude towards the Poles.

IF the Diviſion HG and HK (*Fig.* 44.) be not thro' the Lines drawn, on account of the great Diſtance of the Eye D, it will be eaſy by Calculation

Calculation to find the Parts for every Degree thus:

AS the Diſtance of the Eye, taken from the Center of the Earth, with the Sine of the Complement of the Arch of the Equator to be repreſented, is to the Sine of the ſame Arch; So is the Diſtance of the Eye from the Map, to the Part of the Line H G or A K, which will repreſent ſo much of the Equator.

For Example. Let us ſuppoſe the Eye D to be removed from the Center of the Earth two hundred of it's Semidiameters, and the Map H K one hundred. Then D E will be 200, and D H 100 of ſuch Parts as E B or E A is 1. Let us firſt find the Longitude of G H K, which is to repreſent a Semicircle of the Equator at this Diſtance of the Eye and Map, it will be then,

As D E is to D H, So is E A to H G, or the Semidiameter of the Earth; or as 200 : 100 : : 1 to $\frac{1}{2}$; which ſhows, that G H or G K is to be half of the Length of the Semidiameter of the Earth: which indeed is too great, and can be repreſented on no Plane.

THEREFORE, for the Earth we conceive a ſmall Sphere, whoſe Diameter is two Feet; then H G or H K will be one Foot, on the former Suppoſition.

YET if you would know how much the Eye muſt be removed from the Earth, that the Semidiameter of the Equator E A may make the Projection H G of a given Length, as one Foot (the Semidiameter of the Earth being 19598300) it may be found by this Proportion; ſuppoſing the Diſtance of the Map from the Eye H D to be 100000. As H G is to D H, So is E A to D F, *i. e.* 1 : 100000 : : 19598300 : 1959830000000, of which 18000 make a *Dutch* Mile; which is a great Diſtance.

BUT in practice we do not take the Earth itself, but it's Type, or a little Sphere, from which we need not suppose the Eye to be so far; which will make no Error in the Projection.

The eighth Method; in which any Place may be made the Center of the Map.

IF you would have a Map in which the Situation of all places with respect to some one place, or any other, as also their Distances to be seen and found; there is a Method by which the Superficies of the Earth is so represented, that any place may be made the Center of the Map, and other places lie about it, which Maps please those that erroneously think their Country is in the middle of the Earth, as the *Chinese* do, and the *Jews* did of old.

TO describe such a Map: Let us chuse to have *Amsterdam* in the Center; it's Latitude being fifty two, and the Eye placed in the point opposite to the Zenith, that is the Nadir. The Map will be the plane of the Horizon, or some parallel to it if you would represent more than an Hemisphere; which may be better done in this Map.

LET then E (*Fig.* 45.) be taken on the plane for *Amsterdam*, and having drawn the periphery for the Horizon, divide it into four Quadrants, and each of those into ninety Degrees, B D being the Meridian of the place, B the North point, and D the South. The Diameter A C, the East and West Line, is the Prime vertical, A the West, and C the East, which is ninety Degrees from the place. And all the vertical Circles are represented by strait Lines from the Center E to each point on the Horizon; but 'tis better to omit some of them; you may put a pin in the Center, and turn

a Ruler

a Ruler on it which will serve to draw the Verticals.

THEN divide BD into one hundred and eighty Degrees, as before; drawing from A to each Degree in the Semicircle BCD; the point in EB, which is fifty two Degrees on the Arc BC, is the North-pole; which mark with the Letter P, and the point ED which represents fifty two Degrees (counting from C to D) will be the point where the Equator intersects the Meridian of *Amsterdam*, mark it with Q, and count from it to P the Degrees 1, 2, 3, *&c.*

AND likewise from Q to D, and from B to P, count 38, 39, 40, *&c.* Then taking a point of equal Degrees from P, as 99 and 99, or 88 and 88, *&c.* making that Interval a Diameter, draw the Circle which will be a Circle of Latitude for each Degree; and the Tropics and polar Circles with the Equator.

FOR the Meridians; first draw a Circles thro' A, P, C, which will be a Meridian ninety Degrees from that of *Amsterdam*; the Center of it is M, in BD, drawn to the point N, the South-pole; PN being a Diameter, draw thro' M, FH parallel to AC, extending it to K and L. And divide the Circle PHNF into three hundred and sixty Degrees, and by the help of a Ruler, applied to P, and each Degree, divide the Line KFHL, which will give so many points; thro' which and the two poles the Meridians are to be drawn. The Centers of these Arches are also in the Line KL, and are found as by the former Division of it; but the Meridians between A and E have their Centers between M and L.

HAVING thus described Circles of Latitude and the Meridians, 'tis easy to mark down the places on the Earth, whose Situation from *Amsterdam* is readily seen. And the same Division of EB, should

be on the Ruler, which being laid on E, the place ſhows their Diſtance in Degrees, and in what Point they lie. How this Map may be made by the Globe, we ſhall ſhow in the fourth Method of making particular Maps.

The first Method of making particular Geographical Maps.

WE have ſaid enough to the Deſcription of univerſal Geographical Maps; we ſhall next ſhow how particular Maps are to be made. Maps are made of the great Places, as *Europe*, *Aſia*, *Africa*, *America*, or ſmall Places: if the former, the foregoing Method for general Maps may be uſed; tho' different Methods are to be employed for different places. *Africa* and *America* having the Equator paſſing thro' them, are not eaſily drawn by the firſt Method, but properly by the ſecond; the Eye being placed in the Plane of the Equator, above the Meridian in the middle between their Eaſt and Weſt Bounds. And therefore the Equator is a ſtrait Line, and the Parallels, and the Meridians will be Arches of Circles; but the firſt and ſixth Method are beſt to draw *Aſia* and *Europe*: and the firſt Method is beſt as we ſaid to draw the *Frigid Zones* at the Poles.

FIRST of all a ſtrait Line is to be drawn for the Meridian of the Place over which the Eye is ſuppoſed to be; and to be divided into Degrees, according to the Method before explained; which will be degrees of Latitude: and they are to be marked 1, 2, 3, *&c.* Then from the Tables the moſt ſoutherly and northerly places of the Country are to be limited by two Parallels of Latitude; and theſe are to be cut by perpendicular Meridians thro' which Parallels of Latitude paſs, alſo at

at right Angles; and so each place is marked by it's Latitude and Longitude.

The second Method of drawing particular Maps.

BUT Artificers use another Method in drawing small, or not very large Maps. First there is a Line drawn a-cross the Page, and at the lower end, for the Parallels of the place most southerly; and on it are taken equal Parts, according to the Degree of Longitude the Country extends to; then a Line is raised perpendicular on it's middle, divided into as many Parts as the Degrees of Latitude from the North to the South Part: the bigness of those Parts is known from the Proportion of the Degree in that Parallel they are in hath to the Degree on the Equator. And another Line, parallel to that at the bottom, is drawn at the top, divided into as many equal Parts, as the lower Line; and Perpendiculars are drawn from the Divisions below, to those above, supposing, the Latitude of that above; and that below, not much different, or not much distant from the Equator.

BUT if the Distance from the Equator be great, or the two Latitudes much different, the Parts above and below must not be equal. But they must be in proportion, as a Degree in the Parallel above, is to one in the Parallel below; which Proportion may be known by the Table laid down in *Chap.* iv. And thus having the Meridians and Parallels, you may set down each place, as before.

The third Method of describing particular Maps.

IN representing Provinces of small Bounds, we use another Method for the most Part, which

was explained before; for shewing the Situation of places, and their Distance more accurately.

THE Method is this: There must be found by mathematical Instruments, the Angle of the Position of one place from another; which is to be transferred to Paper. For Example; Let there be five places of a Country to be laid down, according to their Situation and Distance, which we call A, B, C, D, E. (*Fig.* 46.) And let us chuse one, as A, from which the rest, or most of them, may be seen; and with an Instrument observe how they lie from you, or from the Meridian in which you are. Then taking, on the Paper, a point as A, describe a Circle on it (which yet may be omitted if you have a Protractor) and take one Diameter of the Circle for the Meridian of A, as H A K; the other perpendicular to it, as H A K, will show the East and West Point; F being the North, and G the South. Suppose then that A looked from B thirty Degrees between South and East; count so many Degrees on GH, and draw a Line thro' the thirtieth Degree: this shows how B lies from A; and thus the Points the places D and E lie in are to be set down. Then going to one of the other places, whose Distance is known from A, with an Instrument observe the other three places C, D, E. This being done; Let there be drawn on the Paper a Scale of Miles, great or small, as you would have your Map; and on the Line between B and A, set down their Distance known; which will give the place B; and thro' B draw another Meridian, parallel to the former; and making a Circle about B, as about A, draw from it Lines showing the Points that C, D, and E lie in; and where these Lines cut the Lines from A, will be the Places of C, D, E. And the same is to be done, if there had been more places.

The

The fourth Method; by the Globe.

WE may, with the help of the terreſtrial Globe, repreſent Places remote from one another, and know their Situations and Diſtances: yea the whole Superficies of the Earth may be thus laid down; ſo that the given place, or any place, be in the middle of the Map, as in the ſixth general Method; ſo that this Method may be brought in among thoſe for general Maps: but 'tis better not to extend the Map beyond an Hemiſphere. For Example; Let it be propoſed to ſet down all the Places about *Amſterdam*, in their due Situation and Diſtance. Firſt chuſe a point in the Middle, as A, *(Fig. 46.)* and deſcribe a Circle about it; and let F G be the Meridian Line, and H K the Eaſt and Weſt; divide each Quadrant into ninety Degrees.

THEN, on the Globe, bring *Amſterdam* to the Meridian, and elevate the Pole for it's Latitude, fix the Quadrant of Altitude at the Zenith, and bring it about to every Place you would have ſet down; as to the Bounds of *Spain*, *France*, *&c.* and obſerve in each the Angle made by the Meridian, and the Quadrant, *i. e.* the Angle of Poſition, with the Meridian of *Amſterdam*; and alſo the Degrees on the Quadrant between *Amſterdam* and each place; then draw on your Paper Lines from A, according as their bearing is between the four Cardinal places (we ſhall ſhow afterwards how the Trouble of drawing Lines may be ſpared); on theſe Lines are to be ſet down their Diſtances by the Quadrant from a Scale, large or ſmall, as you would have your Map; and you will thus have the ſeveral places.

BUT if the Map is to be large, and the places at a great Diſtance, the Line may be divided by the Laws of Perſpective; by ſuppoſing the Eye at

the Antipodes of *Amsterdam*; and for the Map, we take the Plane of the Horizon for representing an Hemisphere; but if a greater or lesser Part of it, then we take a Plane for the Map, that shall be parallel to that of the Horizon, which is to be distant from it the farther, as what we would lay down is above an Hemisphere. Draw then in another Paper a Circle, whose Center is M, and N O a Diameter, and P Q another, perpendicular; divide N Q into ninety Degrees, and take below Q Degrees in proportion to the excess of what you would represent above an Hemisphere, and thro' R draw a Line to M O parallel to Q M, and from O draw Lines to each Degree of the Quadrant N Q or N Q R, if a greater Portion than N Q; which will divide M Q or S R, into Parts which will be Degrees: then chuse a Line of such a Length as we would have to represent the furthest Distance from *Amsterdam*, which will be about half the Breadth of the Map; that Line is to be divided as M Q or S R, and mark the Parts 1, 2, 3, 4, &c. from that, as a Scale, take the several Distances, and set them on the Lines that go to the places; and you have the Map finished. But the Lines need not be drawn to the places; if you have a Scale, or Ruler, divided as M Q or S R; apply one end to A, and the Scale on the Ruler being brought to Points that show the Bearing of the places, you may set off their Distance, counting from A, on the Ruler.

The fifth Method; for Sea-Charts.

SEA-Charts are strait lined, and have the Meridians all parallel; otherwise than was shown in the last Part of the second Method.

THEY are two-fold; the Degrees on the Meridians being either equal or not; they are made the

the ſame way as in the fourth and fifth Method of general Maps, only they repreſent but little, and have more Sea-Compaſſes on them for finding the Bearings. We ſhall ſhow their Uſe hereafter, for ſailing. The Degrees on the Meridians are nearly equal when a ſmall Part only is exhibited; as the Mediterranean: and if the Latitude be great, or the North and South Parts of the Country far diſtant then they are made unequal.

CHAP. XXXIII.

Of the Distances of Places.

PROPOSITION I.

Having two Points, or Places, on the Globe, to draw from the one to the other an Arc, which shall be the Part of a great Circle on that Globe.

CONCEIVE a right Line drawn from the one point to the other; and from both, two Lines to the Center; these three make a Triangle; which, if extended, will cut the Superficies of the Globe, and the Section will be the periphery of a great Circle; and the Arch between the two places will be what is wanted. Or take with your Compasses a Quadrant of a great Circle, and fixing one Foot at each place, describe two Arches cutting one another; where they intersect will be the Center of a great Circle, that will pass thro' the two points given.

PROPOSITION II.

The shortest Distance between two Places on the Superficies of the Earth, is only one Line, (excepting the Places of the Antipodes) which is the Arch of a great Circle, intercepted between the two Places.

THE shortest Distance between two places, is a strait Line from the one point to the other; as appears by the Definition of *Archimedes*; and is easily deduced from other Definitions: and therefore the shortest Distance between two places on the Surface of the Earth, is a strait Line conceived to be drawn from the one place to the other; but the Superficies of the Earth, being a convex Curve, hence it is that the strait Line, which is truly the shortest Distance of the two places, falls within the Cavity of that Superficies; but we consider only those Distances which are on the Superficies; and therefore we added in the Proposition *on the Superficies of the Earth.* Among the several Ways, the shortest of all is the Arch of a great Circle interposed between two points, drawn as we shewed in the preceding Proposition; and that this intercepted Arch is the shortest of all, appears from this geometrical Theorem. *If the Arches of two unequal Peripheries be taken, whose Chords or Subtenses are the same, the Arch of the greater Periphery, will be less than that of the lesser:* for all circular curve Lines, passing through two points, are parts of smaller Circles, excepting that Arch which is part of a greater Circle; and that this Arch is less than other Curves not circular, (as solid Lines, or the Helix) of which infinite Number may be supposed drawn on the Superficies of the Earth, is shown by others: which Theorem belongs not to Geography, but Geometry; which also shows, that only one Arch of a great Circle can be drawn from one place to another.

PRO-

PROPOSITION III.

The Distance of Places change not

THE way of travelling from one Place to another may indeed change, but the shortest Distance is always the same; except the Surface of the Earth should break asunder: but by Places here, we understand immoveable Points. If indeed the Superficies between two Places rises higher, the Distance is greater; if it fall lower, 'tis shorter.

PROPOSITION IV.

No Place is distant from another, more than two thousand seven hundred German *Miles; of which fifteen make a Degree.*

FOR the Earth's Superficies being spherical, there cannot come in between two Points, an Arch greater than an hundred and eighty Degrees, which is a Semicircle. But an hundred and eighty makes two thousand seven hundred *German* Miles; one Degree being fifteen.

PROPOSITION V.

The Distance of the Antipodes, is two thousand seven hundred German *Miles, or an hundred and eighty Degrees.*

1. THE shortest Distance from the Antipodes is not one Line, but an infinite Number all equal; tho' properly speaking, they cannot be called the shortest Distances, but such as there is no shorter.

2. THE circular Distances between the Antipodes, are all Parts of greater Circles, and not of lesser,

lesser, (as those between Places which are not diametrically opposite) and they are infinite.

3. A great Circle passing thro' two Places passes also thro' the Antipodes of those two Places.

4. THE Distances of a Place from two Places that are Antipodes to those two Places, make one hundred and eighty Degrees; and the Distance from the one being known, the Distance from the other is also known.

5. THESE five Propositions are so plain, that any one who considers them, will understand them.

PROPOSITION VI.

A Place on the Surface of the Globe being given, to find all those Places that have the same Distance from it; but the Distance must not be more than two thousand seven hundred German *Miles.*

ELEVATE the Globe for the Latitude of the Place, bring it to the Meridian, fix the Quadrant of Altitude at the Zenith, count on it the Degrees of Distance, and mark with Chalk where they end; then turn the Index round, and the Chalk will go over all those Places that are at the given Distance: or take with your Compasses the Degrees of Distance from the Equator, and fixing one Foot at the given Place, turn the other about, over all the same Places sought; and if the Distance be greater than ninety Degrees, take it's Supplement to one hundred and eighty, and fixing one Foot at the Antipodes of the Place, revolve the other. And if you would use the Quadrant, bring the Antipodes to the Zenith; and fixing the Quadrant there, turn it round: and where the Supplement of the Distance ends, you will have the Places sought under it in a Circle.

PRO-

PROPOSITION VII.

Whence it is that the Distance in Journies is greater than the shortest, or geographical, Distance.

1. FROM Woods that lie between, and are impassable. 2. High Mountains, and deep Vallies. 3. Bogs, Lakes, and in general the Waters we meet with in travelling by Land. 4. In Sea Voyages there are Lands that run out into the Sea, and Islands that hinder a strait Passage. 5. A peculiar flowing of the Seas. 6. The Winds.

BUT some may ask, are there not Land Journies shorter than Geographical, or the shortest, Distance. To which I answer, tho' the Earth's Figure is spherical, so far as can be discerned; yet in the first Book we showed it was not Geometrically so altogether; but raised and depressed unequally in several Places: and if there be two Places that are distant from the Earth's Center, eight hundred and sixty Miles, and the Space between them depressed, then the Land-Journey, *cæteris paribus*, will be shorter than the Geographical Distance; as the Chord is lesser than the Arch.

PROPOSITION VIII.

To find the Distance of two Places on the Globe, or on the Maps made for particular Places.

BRING one of the Places to the Zenith, and fix the Quadrant there, and turn it 'till it come to the other; then count the Degrees between them, and turn them to Miles, or take their Distance with the Compasses, and see how many Degrees it makes on the Equator; but if the Distance be

greater

greater than ninety Degrees, you must, as in *Prop.* vi, take the Supplement to one hundred and eighty, or it's Distance from the Antipodes, by bringing their Place to theZenith, and applying the Quadrant there; and that Distance in Degrees, taken from one hundred and eighty, gives the other Distance above ninety Degrees.

THIS Distance is not exactly found in universal Maps, but in particular Maps there uses to be a Scale of Miles added; and taking the Distance with the Compasses, and applying it to that Scale you have the Miles, or Leagues, contained in it.

BUT this Method will not hold if it be a Map of a large place; for no Map can be made that will show truly all Distances: tho' a Map may be made to show the Distance of one place, from all other places, as we saw in the Construction of Maps.

PROPOSITION IX.

Having the Latitude and Longitude of two Places to find their Distance.

THE Solution of this by the Globe is easy, or by an universal Planisphere; but difficult, tho' accurate, by spherical Trigonometry.

ON the Globe thus: Take any Meridian at pleasure; 'tis better to take the Meridian of one of the places if it be drawn; or, which is more commodious, take the first Meridian, and count from it on the Equator the Difference of the Longitude of the places; and where that Number ends, must be brought under the brass Meridian, and the Latitude of both places marked on their Meridians; and taking the Distance of the two Marks, with the Compasses, apply it to the Equator; and you have the Distance in Degrees: if it be more

more than ninety, you muſt take a Thread well ſtretched, and apply it.

BECAUSE a Planiſphere is fitter for uſe eſpecially to Sailors, that have frequent occaſion for this Problem, and love to uſe that Inſtrument, we ſhall here explain the Method.

THERE are two Caſes in the Problem; either firſt, the Places have the ſame Longitude; or have one hundred and eighty Degrees of Difference in Longitude; and then you need only turn the Difference of Latitude, or the Degrees of Diſtance on the Meridian to Miles: and if the one Latitude be North, the other South, you muſt add their Latitude; which is eaſily done by taking the Degrees between the two Places.

BUT if the Places are in different Meridians, and out of the Equator you muſt do otherwiſe.

AND it will firſt be uſeful to ſhow the Caſes in which the Solution varies: and that will make it very eaſy; as will appear by Examples, in which Students ſhould exerciſe themſelves.

1. IF the Places have the ſame Longitude, and have Latitudes of the ſame Kind; then the Difference of Latitudes in Degrees may be turned to any other Meaſure.

2. IF they have the ſame Longitude, and their Latitudes of different Kinds, the one North, the other South; then add the Latitudes, and you have the Diſtance in Degrees.

3. IF the Difference of Longitudes be one hundred and eighty Degrees, and they have different Latitudes, take the Difference of Latitude, and ſubſtract it from one hundred and eighty Degrees; what remains will be the Diſtance in Degrees.

4. IF the Difference of Longitude be one hundred and eighty Degrees, and they have the ſame kind of Latitude; add the Complement of their Latitude, and you have the Diſtance in Degrees.

5. IF

5. IF both Places are in the Equator, then the Difference of Longitude in Degrees is the Diſtance.

6. IF both Places have the ſame Latitude, and not more than twenty Degrees, and the Difference of Longitude be ſmall, enter with that Latitude the Table of the Parallels bigneſs, in *Chap.* iv, and take out the Quantity of one Degree in that Parallel; then take the Difference of Longitude, and multiply it by the Miles in one Degree.

7. IF both Latitude and Longitude differ, or if the Latitudes be the ſame, but above twenty Degrees; and the Difference of Longitude great; which often occurs; we muſt not follow the former ſhort Methods, but be at more Pains; and for this chiefly is the Problem propoſed.

WE have given a Solution by the Globe; and by the Planiſphere it may be done thus: Bring the Rule of the Planiſphere to the Latitude of the Place; then count the Difference of Longitudes in the Meridians, beginning at the other Part; and where the Meridian, that terminates that Number, cuts the Parallel of the other Latitude, place there the end of the Index; then apply the Ruler to the Equator; and the Number of the Parallels between the Pole, and the Index, is the Diſtance ſought in Degrees.

THERE is another Method, invented by *Maurolicus*, which ſhows the Diſtance in a pleaſant Manner, by drawing a Line in a Circle; from which Method, that of ſolving it by Calculation proceeds.

ON the Center E (*Fig.* 48.) deſcribe a Circle, BE being one Semidiamater; and let the Arc BA be taken equal to the Difference of Longitude (if it be greater than one hundred and eighty, take it's Complement to three hundred and ſixty) and draw AE; then take AF towards B, equal to

 the

the Latitude of the Place A, and from B the Arc B G, equal to the Latitude of B; and let GI, be made perpendicular to B E and F H, from F to A E, draw I H, and on I and H raiſe perpendiculars I, L, equal to I G, and H K equal to H F (the ſame way if the Latitude be of the ſame kind, if not then I L is to be drawn on the one Side of I H and H K on the other) then L K will be the Chord of the Diſtance ſought; and with the opening of the Compaſſes K L, take B X, and you have the Diſtance in Degrees.

THIS Method is taken from the Solution of ſpherical Triangles; but the doing of it by drawing Lines doth not give the Diſtance exact enough; tho' 'tis eaſy and pleaſant; and no other Method by ſpherical Trigonometry can give it exact enough. You have the Complements of the two Latitudes, and the Angle contained, which is the Difference of Longitude, to find the oppoſite Side, which is the Diſtance ſought; for which there are ſeveral Methods, but the moſt common, and what hath no regard to the variety of Caſes here, is this:

1. IF the Latitudes are of one kind, then let it be, As the Square of the Radius is to the Rectangle of the Sines of the Complement of the Latitudes, So is the verſed Sine of Difference of Longitudes (if greater than one hundred and eighty, take their Complement to three hundred and ſixty) to a certain fourth Number; then take the Difference of the Latitudes, and the Sine of it's Complement; then the fourth Number, found before, compared with this Sine; and if they be equal, then the Diſtance is ninety Degrees; if leſs, ſubſtract it, and the Remainder will be the Sine of an Arc, whoſe Complement is the Diſtance of the Places; but if greater than the ſaid Sine, ſubſtract the one from the other, and the Remainder will be the Sine of an Arc, which being added to

ninety Degrees, gives the Diſtance ſought in Degrees.

2. IF the Latitudes be of different kinds, then take the Place of one of the Antipodes for the other Place, and find their Diſtances by the former Method; for the Latitude thereof will be the ſame, as the other; and there will ariſe a ſpherical Triangle, and two Sides given; and the Angle included will be the Complement of the Difference of Longitude to one hundred and eighty Degrees: and having found the Diſtance between the one Place, and the Antipodes of the other; you have the Diſtance of the Places themſelves for it's Complement of the former to one hundred and eighty, as was ſaid in the preceding Propoſition.

IN Places that are nearer the Equator than nineteen Degrees, we may uſe another eaſy Method; which tho' not demonſtrative, yet will give the Diſtance pretty nearly. We take the Square of the Difference of Longitude, and the Square of the Difference of Latitude; and their Sum is the Square of the Diſtance nearly.

OR better thus, which will ſerve for great Latitudes; find, by the Table before, the Miles in the Parallel of the greateſt Latitude; then As the Miles in a Degree on the Equator are to the Miles in a Degree in that Parallel; So is the Difference of Longitude in Miles to a fourth Number; the Square of which added to the Square of the Difference of Latitude in Miles, gives the Square of the Diſtance.

THE Solution will be the eaſier if we uſe the Logarithms, and reſolve the oblique Triangle into two right-angled Triangles; for then there will be no need of Multiplication and Diviſion.

PROPOSITION X.

Having the Difference of Longitude of two Places, and the Point on which one lies from the other, to find their Distance.

THIS is no other than having two Sides of a ſpherical Triangle, and the Angle oppoſite to one Side, to find the third Side; or having the Complements of two Latitudes, and the Angle of Poſition, or it's Complement, to one hundred and eighty, to find the third Side.

THE Solution of the Problem by the Globe is thus: Suppoſe the firſt Meridian to be the Meridian of the Place, and mark the Latitude for that Place; then elevate the Globe for the Latitude of the other Place, and fix the Quadrant to the Zenith and turn it 'till it come to the Point given on the Horizon; then turn the Globe 'till the Place whoſe Latitude was marked come to the Quadrant; then the Arc of the Quadrant between the Zenith and that Point is the Diſtance ſought: at the ſame time you have the Difference of Longitude on the Equator, or the Arc between the firſt, and the braſs Meridian.

HOW this is to be done by the Planiſphere, and by Calculation, with, or without, the Logarithms, I leave to a Maſter; leſt I ſhould ſay a great deal that would be of little uſe to many.

PROPOSITION IX.

Having the Longitude of two Places, and the Latitude of one, and the Point in which the other Place lies in from it, to find the Diſtance.

WE have here again a ſpherical Triangle, whoſe Sides are the Complements of the two Latitudes, and

and the Diſtance of the Places in which we have one Side, the Complement of the Latitude of the one, and two Angles; the one is the Difference of Longitude; and the other the Point made by the Meridian and the Diſtance, to find the Diſtance. The Solution by the Globe and the Planiſphere is eaſy, and by Logarithmical Calculation accurate enough; and even by common Calculation: we ſhall only uſe the way by the Globe for the Reaſon before mentioned; though by the Planiſphere 'tis eaſier; but that by the Globe gives the Triangle itſelf.

SUPPOSE the firſt Meridian to be that of the place whoſe Latitude is not given; count the Difference of Longitude on the Equator, and mark the ending with Chalk, and bring it to the Meridian which will be the Meridian of the other place; count on it the given Latitude; and elevate the Pole for that Latitude; the Globe being fixed, bring the Quadrant to the Zenith, and turn it 'till it come to the Point on the Horizon; the Place where the Quadrant cuts the firſt Meridian will be the one place, and the Arc between the Zenith; and that Point is the Diſtance ſought. And at the ſame time you will ſee the Latitude of the other place.

PROPOSITION XII.

Having the Diſtance of two Places in the ſame Meridian, and the Points in which a third lies from the other two, to find the Diſtance of the third from the other two.

WE have here again a ſpherical Triangle, in which the three Sides are the three Diſtances of the Places, and one Side is given; the Diſtance of the two in the ſame Meridian, and the two

adjacent Angles, and the other two Sides are wanted.

OMITTING the Methods by Calculation, and by the Planiſphere (tho' more accurate) we ſhall give that by the Globe; which exhibits the thing to the Eye.

TAKE the Diſtance of the two places in the braſs Meridian; then elevate the Pole for the Latitude of the one, and fix the Quadrant at the Zenith, and bring it to the Point the third place lies in, and draw a Line along it with Chalk; then fix the Quadrant at the other place brought to the Zenith, and turn it 'till it comes to the Point the third place lies in from the ſecond place; and where it cuts the Arch by the Chalk, you have the third place, whoſe, Diſtance from the other two is eaſily meaſured,

CHAP.

CHAP. XXXIV.

Of the Sensible or Visible Horizon.

THE Sensible Horizon is a Periphery on the Superficies of the Earth, which terminates the Sight all round, or which terminates that Part of the Superficies visible to the Eye, whilst the Spectator turns himself round; or from which Rays can come to the Eye. It's Semidiameter is an Arc of a great Circle on the Earth, between the Foot of the Spectator and the Periphery, which is therefore perpendicular to that Periphery.

PROPOSITION I.

The Extension of the Sensible Horizon is various, according to the Height of the Eye; or as the Semidiameter of the Earth is supposed to be.

Let MPNF (*Fig.* 49.) be a great Circle on the Earth, T the Center, TP the Semidiameter, PO the Altitude of the Eye, and O the Eye; draw from O the Tangents ON, OM; and let us conceive the Ray NO to be carried round, and to describe a Periphery on the Earth; which will be the Sensible Horizon, whose Semidiameter is PN, PM, for NO, MO, are the last Rays that can come to the Eye from the Earth; which we here suppose perfectly round.

AND 'tis plain if we take a greater or less Altitude PO, then PN will be a greater or lesser

Arc; and if T P be more or fewer Miles, then P N will be ſo alſo.

THESE two ſeem to be the Cauſes why the Antients differ ſo much in their Opinions of the bigneſs of this Horizon. *Macrobius* makes the Semidiameter of it one hundred and eighty Furlongs, or twenty two Miles and a half; and *Eratoſthenes* three hundred and fifty Furlongs, or forty four Miles; *Albertus Magnus* a thouſand Furlongs, or one hundred and twenty five Miles; *Proclus* two thouſand Furlongs, or two hundred and fifty Miles; a great many make it five hundred Furlongs, or ſixty two Miles and a half: which Diverſity proceeds alſo from the different Lengths of Furlongs, as appears from the following Propoſition.

PROPOSITION II.

Having the Height of the Eye above the Ground, and the Semidiameter of the Earth; to find the Semidiameter of the Senſible Horizon.

Let P O (*Fig.* 49.) be the Man's Stature, O the Eye, T P the Semidiameter, O N the Ray touching the Earth, which terminates that Horizon; therefore P N is it's Semidiameter, whoſe Length is wanted: P O being ſuppoſed five Foot, is added to the Semidiameter T P, which makes T O 19598300 Feet; and in the Triangle N T O we have T O and T N, and the Angle T N O ninety Degrees; the Angle N T O is found thus, As T O is to T N, So is the whole Sine to the Sine of the Angle N O T; whoſe Complement is the Angle N T O, or Arc N P, which may be turned to Miles.

COROL-

COROLLARY.

FROM hence we may see, that if T P or P O be taken of different Lengths, there will come out different Degrees in the Arc N P.

PROPOSITION III.

Having the Height of the Eye on a Tower, or Mountain, to find how far the Sight extends on the Sea.

Let P O (*Fig.* 49.) be the Altitude of the Tower, and work as before; for here the Height of a Man is not considerable.

PROPOSITION IV.

The greatest Length that the Sight extends being given; or the Semidiameter of the Sensible Horizon; to find at what Height the Eye is placed.

OR, which is the same thing, having the greatest Distance that the Top of a Mountain can be seen at, to find the Altitude of the Mountain

IN the Triangle N T O (*Fig.* 49.) there is given the Angle at N of ninety Degrees; and the Arc N P, which is the Measure N T O, and the Semidiameter N T, to find T O, from which take T P, and you have P O.

WE may therefore, by supposing a certain Measure of the Semidiameter of the Earth, find, from the Quantity assigned, by different Authors, to the visible Horizon, what Height of the Eye each Author assumed.

PRO-

PROPOSITION V.

Having the Height of the Eye, and the Height of a Ship's Mast, or a Tower, or Mountain, to find their Distance.

Let P O (*Fig.* 49.) be the Height of the Eye on the Mast of a Ship, or Tower, *&c.* and F S the Mast of another Ship, then S O will be the first Ray that comes to the Eye from the Top-Mast, the Distance F P is wanted. First from the Triangle N T O; having N T, and T O, and the Angle T N O, find the Angle N T O, and the Triangle N T S; having N T, and T S; and the right Angles T N S; find the Angle N T S; thus you have the whole Angle O T S, of which the Arc P F is the Measure.

PROPOSITION VI.

Having the Height of the Eye, and the Distance at which the Ship or Tower is first seen, to find the Altitude of the Tower or Ship.

IN the Triangle N O T, (*Fig.* 49.) having N T and T O, the Arc N P is found, which being taken from the known Arc P F (the Distance being turned to Minutes of a Degree) leaves the Arc F N, or the Angle N T S. And in the Triangle N T S you have N T, and the Angle N ninety Degrees; you may find the Hypotenuse T S, from which take T F, and you have the Height of the Tower, Ship, *&c.*

PRO-

PROPOSITION VII.

The Refraction of Light in the Air increases the apparent Semidiameter of the Sensible Horizon.

FOR the Refraction differs in different places, the Air being thicker, the nearer the Earth; and therefore tho' the Ray come from a Point further than N, (*Fig.* 49.) as from F, it cannot come strait to the Eye, yet may be refracted so as to come in the Line N O, which touches the Earth.

IT may not be improper here to observe, that our learned Auther is, as it were, the Fountain from whence most of our Geographical Writers have drawn very great Supplies; some have borrowed and acknowledged the Advantages; others have stolen from him, and, in a different Dress and Dialect, have recommended it to the World for their own. It is certain that to borrow from an Author, and to improve upon that Auther, is not only justifiable, but has been the chief if not the only means by which the present Age has brought their Acquirements in Philosophy, and Mathematics, to the pitch to which they are now arrived; therefore to do justice to Mr *Gordon* in his Grammar, and yet to improve *Varenius* so as to make it the most excellent of it's Kind, the Publisher hath thought proper to add not only some *Theorems* which in themselves are natural and demonstrable Truths, beyond the reach of Contradiction, or even of Dispute; but also some of the most useful of *Gordon*'s *Paradoxes*, with their Solutions, without which the Paradoxes are but of little use except to amuse the Reader, and leave him as much in the Dark as they found him. The *Theorems* follow immediately, and the *Paradoxes* with their Sulutions next after them.

GEOGRAPHICAL THEOREMS.

Theor. 1. The Latitude of any place is always equal to the Elevation of the Pole in the ſame place, and *è contra.*

Theor. 2. The Elevation of the Equator in any place is always equal to the Complement of the Latitude in the ſame place; and *vice verſâ.*

Theor. 3. Thoſe places lying under the Equinoctial Line have nothing of Latitude, it being there that the Calculation of Latitude begins.

Theor. 4. Thoſe places lying exactly under the the two Poles have the greateſt Latitude, it being there that Calculation of Latitude doth end.

Theor. 5. Thoſe places lying exactly under the firſt Meridian have nothing of Longitude, it being there that the Calculation of Longitude begins.

Theor. 6. Thoſe places lying immediately adjacent to the weſtern Side of the firſt Meridian have the greateſt Longitude, it being there that the Calculation of Longitude doth end.

Theor. 7. All places lying upon each Side of the Equator, have the greater or leſſer Latitude, according to their reſpective diſtance therefrom.

Theor. 8. All places lying upon either Side of the Equator, and exactly under the ſame, have the greater or leſſer Longitude according to their reſpective diſtance from the firſt Meridian.

Theor. 9. That particular place of the Earth lying exactly under the Interſection of the firſt Meridian and Equinoctial Line, hath neither Longitude nor Latitude.

Theor. 10. No place of the Earth is diſtant from another above 10800 *Italian* Miles allowing 60 to one Degree in the Equator.

Theor. 11. No place of the Earth is diſtant from it's proper Antipodes, diametrically taken, above

7200 *Italian* Miles, ſtill allowing 60 to one Degree in the Equator.

Theor. 12. The ſenſible Horizon of every place doth as often change as we happen to change the place itſelf.

Theor. 13. The apparent Semidiameter of the ſenſible Horizon in moſt places doth frequently vary, according to the Refraction of the Sun-Beams.

Theor. 14. All Countries upon the face of the whole Earth do equally enjoy the ſight of the Sun in Reſpect of time, and are equally deprived thereof.

Theor. 15. In all places of the Globe of the Earth, ſave exactly under the Poles, the Days and Nights are of an equal Length, *viz.* 12 Hours each, when the Sun cometh to the Equinoctial Line.

Theor. 16. In all places between the Equinoctial and the two Poles, the Days and Nights are never equal one to another, ſave only thoſe two times of the Year when the Sun entereth the Signs of *Aries* and *Libra.*

Theor. 17. The nearer any place is to the Line, the leſſer is the difference between the length of the Artificial Days and Nights in the ſaid place: and, on the contrary, the further removed the greater.

Theor. 18. In all places lying under the ſame Parallel of Latitude, the Days and Nights are of the ſame Extent, and that at all times of the Year.

Theor. 19. Three or more places being given on the Globe, that lie between the Equator and either of the Poles, and equidiſtant from one another, the extent of the longeſt Day in thoſe places doth not increaſe proportionably to the diſtance of the places themſelves.

Theor.

Theor. 20. Three or more places being given on the Globe, that lie between the Equator and the Poles, in which the length of the longest Day doth equally increaſe, the Diſtance between the Parallel of thoſe places is not equal to one another.

Theor. 21. Three or more places being given one the Globe, whoſe Diſtance from the Equator to either Pole exceeds one another in Arithmetical Proportion; the Length of the longeſt Day in one doth not keep the ſame Analogy to that in the other, according to the Proportion of their Diſtance.

Theor. 22. In all places of the *Torrid Zone* the Morning and Evening Twilight is leaſt: in the Frigid greateſt; and in the temperate 'tis a Medium between the two.

Theor. 23. To all places lying between the Tropics, the Sun is duly vertical twice a Year; to thoſe under the Tropics once; but to them in the Temperate and Frigid never.

Theor. 24. In all places of the two *Frigid Zones*, the Sun appeareth every Year without ſetting for a certain number of Days, and diſappeareth for the ſame Space of Time. And the nearer unto or the farther from the Pole theſe places are, the longer or ſhorter is his continued preſence in, or abſence from, the ſame.

Theor. 25. In all places exactly under the Arctic and Antarctic Circles, the Sun at his greateſt Declination appeareth every Year, for one Day compleatly without ſetting, and intirely diſappeareth another, but daily riſeth and ſetteth in thoſe Parts at all other Times as elſewhere.

Theor. 29. In all places between the Equator and North Pole, the longeſt Day and ſhorteſt Night is always when the Sun hath the greateſt northern

northern Declination, and the ſhorteſt Day and longeſt Night when he hath the greateſt Southern.

Theor. 27. In all Places between the Equator and South Pole, the longeſt Day and ſhorteſt Night is always when the Sun hath the greateſt ſouthern Declination; and the ſhorteſt Day and longeſt Night, when the greateſt Northern.

Theor. 28. In all places ſituated under the Equinoctial Line, the Meridian Shadow of a Style perpendicularly erected, doth caſt itſelf towards the North for one half of the Year, and towards the South during the other.

Theor. 29. In all places lying under the Equinoctial Line, there is no Meridian-Shadow on thoſe Days of the Year that the Sun doth enter the Signs of *Aries* and *Libra*.

Theor. 30. The nearer that Places are unto, or the fartheſt removed from, the Equator, the ſhorter or longer accordingly is the Meridian-Shadow of a Style perpendiculary erected in ſuch Places.

Theor. 31. The farther that Places are removed from the Equator, yet not ſurpaſſing 66 Degrees of Latitude, the greateſt is the Sun's Amplitude, or that Arc of the Horizon between the Points of due Eaſt and Weſt, and thoſe on which the Sun riſeth and ſetteth on the Days of the Summer and Winter *Solſtice*.

Theor. 32. In all places lying under the ſame Semicircle of the Meridian, the Hours of both Day and Night are always the ſame in one as in the other.

Theor. 33. In all places both of the North and Southern Hemiſpheres, that lie under the oppoſite Parallels of Latitude, the Seaſons of the Year are not the ſame in one, as in the other.

Theor. 34. In all places ſituated in a parallel Sphere, the Circle of the Sun's Diurnal Motion runs

runs always parallel, or very near it, to the reſpective Horizon of ſuch places.

Theor. 35. In all places ſituated in a right Sphere, the Circle of the Sun's Diurnal Motion is ſtill perpendicular, or very near it, to the reſpective Horizon of ſuch places.

Theor. 36. In all places ſituated in an Oblique Sphere, the Circle of the Sun's Diurnal Motion is always oblique unto, or cutteth, the Horizon of ſuch places at unequal Angles.

Theor. 37. If the Difference of Longitude in two places be exactly 15 Degrees, the People reſiding in the Eaſtmoſt of them, will reckon the time of Day ſooner by one Hour, than thoſe in the other. If the Difference be 30 Degrees, then they'll reckon the Hours ſooner by two; if 45 Degrees, by three; and if 60, then by four, *&c.*

Theor. 38. If People reſiding in two diſtinct places do differ exactly one Hour in reckoning their Time, it being only Noon to one, when One in the Afternoon to the other, the true Diſtance between the reſpective Meridians of thoſe Places is exactly 15 Degrees upon the Equator: If they differ two Hours, the Diſtance is 30 Degrees; if three, 'tis 45; and if four, 'tis compleatly 60, *&c.*

Theor. 39. If any Ship ſet out from any Port, and ſteering Eaſtward doth entirely ſurround the Globe of the Earth, the People of the ſaid Ship in reckoning their time will gain one Day compleatly at their Return, or count one more than thoſe reſiding at the ſaid Port: If Weſtward, they'll loſe one, or reckon one leſs.

Theor. 40. If two Ships ſet out from the ſame Port at the ſame time, and both ſurround the Globe of the Earth, one ſteering Eaſt and the other Weſtward, they'll differ from one another in reckoning their

their time two Days compleatly at their Return, even ſuppoſe they happen to arrive on the ſame Day. If they ſurround the Earth twice, ſteering as aforeſaid, they'll differ four Days; if thrice, then ſix, *&c.*

Theor. 41. If ſeveral Ships ſet out from the ſame Port, either at the ſame or different time, do all ſurround the Globe of the Earth, ſome ſteering due South, others due North, and arrive again at the ſame Port, the reſpective People of thoſe different Ships at their Return will not differ from one another in reckoning their time, nor from thoſe who reſide at the ſaid Port.

GEOGRAPHICAL PARADOXES,

With their SOLUTIONS.

Paradox 1. There are two remarkable places on the Globe of the Earth, in which there is only one Day and one Night throughout the whole Year.

Solution. Thoſe two places are moſtly all that Space contained within the Polar Circles, as is evident from *Prop.* 15.

Paradox 2. There are alſo ſome places on the Globe of the Earth, in which there is only one Day and one Night at a certain time of the Year.

Solution. Theſe two places are the Polar Circles, when the Sun is in the oppoſite Tropic, as appears from *Prob.* 15 and 16.

Paradox 3. There is a certain place of the Earth, at which if two Men ſhould chance to meet, one would ſtand upright upon the Soles of the other's Feet, and neither of them ſhould feel the other's Weight, and yet both ſhould retain their natural Poſture.

Solution. This place is the Center of the Earth: This Paradox is rendered obſcure, by ſaying a certain place of the Earth, and not in the Earth.

Paradox 4. There is alſo a certain place of the Earth, where, a Fire being made, neither Flame nor Smoak would aſcend, but move circularly about the Fire. Moreover, if in that place one ſhould fix a ſmooth or plain Table without any Ledges whatſoever, and pour thereon a large Quantity of Water, not one Drop thereof could run over the ſaid Table, but would raiſe itſelf up in a large Heap.

Solution. This is likewiſe the Center of the Earth; but theſe two laſt Paradox may rather be termed Philoſophical than Geographical.

Paradox 5. There is a certain place of the Globe, of a conſiderable Southern Latitude, that hath both the greateſt and leaſt Degree of Longitude.

Solution. Not only a certain place in Southern Latitude, but all places, ſituated under the firſt Meridian from Pole to Pole, have the greateſt and leaſt Degree of Longitude; becauſe where the utmoſt Extent of Longitude ends, it's leaſt Denomination begins.

Paradox 6. There are three remarkable places on the Globe, that differ both in Longitude and Latitude, and yet all lie under one and the ſame Meridian.

Solution. This is to be underſtood of the Artificial Globe, and the brazen Meridian thereto belonging; then the Difficulty will ſoon vaniſh, if we ſuppoſe the firſt place to be ſituated 10 Degrees of Latitude, and 10 Degrees of Longitude, from any firſt Meridian, the ſecond place under the North Pole, and the third in 190 Degrees of Longitude under the Tropic of *Cancer*: Then it will appear, that all three places are under the ſame brazen Meridian of the Artificial Globe, and yet differ both in

Longitude

Longitude and Latitude, for the first place will be in 10 Degrees Longitude and 10 of Latitude; the second in 0 Longitude and 90 Degrees Latitude; the third in 190 Degrees Longitude, and 23° 30′ Latitude.

Paradox 7. There are three remarkable places on the Continent of *Europe*, that lie under three different Meridians, and yet all agree in Longitude and Latitude.

Solution. 'Tis supposed that this refers to the Difference among Geographers in fixing their first Meridian. Thus some place it at *Cape de Verd* Islands, and others at *Teneriffe*, one of the *Canary* Islands. Now if you take three places in *Europe* to make it correspond with the Paradox, in the same Latitude, at 10 Degrees distant from one another, and supposing each place to be the first Meridian, they all agree in Latitude, and also in Longitude, and yet lie under three different Meridians in respect of the Globe.

Paradox 8. There is a certain Island in the *Ægean* Sea, upon which if two Children were brought forth at the same instant of Time, and living together for several Years, should both exspire on the same Day and Hour, yet the Life of the one should surpass the Life of the other by divers Months.

Solution. This Paradox may be solved two ways:

1. If one of the Children sail directly East, and the other directly West, when they encompass the Globe, which may be done in a Year, there will be two Days difference in their Ages; and in 40 Years thus sailing, the one will be 80 Days older than the other.

2. Otherwise, if we suppose the one to live within the Artic Circle, where no Day exceeds 24 Hours; and the other lives within either of

the Polar Circles, as under 73° 20′, where the Day is three Months long, and then returns, and both die, the one will be three Months older than the other.

Paradox 9. There are two obſervable places belonging to *Aſia*, that lie under the ſame Meridian, and of a ſmall Diſtance from one another, and yet the reſpective Inhabitants, in reckoning their Time, do differ an entire natural Day every Week.

Solution. Not only in *Aſia*, but every where elſe, where *Chriſtians* and *Jews* inhabit together, the latter reckon their Sabbath one Day every Week ſooner than the former,

Paradox 10. There is a particular place of the Earth, where the Winds, tho' frequently veering round the Compaſs, do always blow from the North.

Solution. At the South Pole.

Paradox 11. There is a certain Hill in the South of *Bohemia*, on whoſe Top if an equinoctial Sun-Dial be duly erected, a Man that is Stone-blind may know the Hour of the Day by the ſame.

Solution. If a Burning-Glaſs be the *Nodus* of a Dial, and ſo contrived, that the *Focus* may fall on an iron or braſs Plate or Ring, on which the Figures are deeply cut, a blind Man may feel where the Plate or Ring is heated by the Sun, and which Figure it is upon, or neareſt to.

Paradox 12. There are a conſiderable number of Places lying within the *Torrid Zone*; in any of which, if a certain Sun-Dial be duly erected, the Shadow will go back ſeveral Degrees upon the ſame at a certain time of the Year, and that twice every Day for the Space of divers Weeks, yet no ways derogating from that miraculous returning of the Shadow upon the Dial of *Ahaz* in the Days of King *Hezekiah*.

Solution.

Solution. This Paradox may be solved by explaining the nature of concave, convex, and reflecting Dials; but as one certain kind of Dial is mentioned, we may suppose a plain equinoctial Dial described on both Sides of an horizontal Plane with two Gnomons, and near the Tropic, when the Latitude and Declination are equal; before the Sun comes to the mathematical Horizon in the Morning, he will shine on the lower Side of the Plane, and the Shadow of the Gnomon will run Westward; and presently after six o'Clock, as he shines on the upper Plane, the Shadow will run Eastward 'till Noon, and thence to six in the Evening, at which time the Shadow on the lower Plane will begin and run Eastward 'till Sun-set.

Likewise it may be considered, that any where in the *Torrid Zone*, where the Latitude is less than the Sun's Declination, and both towards the same Pole, the Sun comes twice to the same Point of the Compass both Forenoon and Afternoon; and an equinoctial Dial placed horizontally, the Shadow of the Gnomon shall go back twice every Day.

Paradox 13. There are divers places on the Continent of *Africa*, and the Islands of *Sumatra*, where a certain kind of Sun-Dial being duly fixed, the Gnomon thereof will cast no Shadow at all during several Seasons of the Year, and yet the exact time of the Day may be known thereby.

Solution. Horizontal Dials within the Tropics cast no Shadows at 12 o'Clock twice every Year; nor will any universal Ring-Dial shew the Hour in any Latitude, when the Sun is in either Equinox.

Paradox 14. There is a certain Island in the vast *Atlantic* Ocean, which being described by a Ship at Sea, and bearing due East of the said Ship, at 12 Leagues distant by Estimation, the truest

Courſe for hitting the ſaid Iſland is to ſail ſix Leagues due Eaſt, and juſt as many due Weſt.

Solution. If it be ſuppoſed, that the firſt Meridian from whence Longitude is reckoned both ways, paſſes in the Middle between the Ship and Iſland; then Regard is had to the Eaſt and Weſt Longitude and not to the Points of the Compaſs.

Paradox 15. There is a remarkable Place on the Globe of the Earth of a very pure and wholſom Air to breathe in, yet of ſuch a ſtrange and deteſtable Quality, that 'tis abſolutely impoſſible for two of the entireſt Friends that ever breathed to continue in the ſame, in mutual Love and Friendſhip for the Space of two Minutes of Time.

Solution. 'Tis certainly impoſſible for two Bodies of any kind to be in one and the ſame Place at the ſame Time.

Paradox 16. There is a certain noted Place in the vaſt *Atlantic* Ocean, where a briſk Levant is abſolutely the beſt Wind for a Ship that is to ſhape a due Eaſt Courſe, and yet ſhe ſhall ſtill go before it.

Solution. This Paradox may be ſolved ſeveral ways:

1. If the Place be Eaſtward of the *Levant*, a Ship may be carried by an Eaſt Wind round the Globe to it, provided ſome Eaſt Point be fixed.

2. 'Tis the Caſe in the Gulph of *Florida*, where there's a violent Current, as is well known to moſt Seamen that have been in the *Weſt-Indies*.

Laſtly, An Eaſt Wind may be beſt to carry a Ship out of an Harbour, that is to ſail or make an Eaſtern Voyage, as in the Port of *London*, a Weſtern Wind is beſt to bring ſuch Ships out of the *Thames*, tho' bound to the *Weſt-Indies*.

Paradox 17. There are divers remarkable Places upon the Terraqueous Globe, whoſe ſenſible Hori-

zon is commonly fair and serene, and yet 'tis impossible to distinguish properly in it any one of the intermediate Points of the Compass, nay, not so much as the two of the four Cardinal Points.

Solution. This must be meant under either of the Poles.

Paradox 18. There is a certain Island in the *Baltic* Sea, to whose Inhabitants the Body of the Sun is clearly visible in the Morning before he riseth, and likewise in the Evening after he is set.

Solution. There is no Difficulty in this Paradox to any one who is acquainted with the Nature of Refraction; but to such who are not, if they please to put a Sixpence into a Vessel of Water, and stand at such a Distance that they can just see the Sixpence, or any other piece of bright Metal; and when the Vessel is empty they cannot see the Metal at the same Distance: So the watry Vapours, near the Horizon, causes the Sun to appear to be higher than he really is.

Paradox 19. There is a certain Village in the Kingdom of *Naples* situated in a very low Valley, and yet the Sun is nearer to the Inhabitants thereof every Noon by 3000 Miles and upwards, than when he either riseth or setteth to those of the said Village.

Solution. When the Sun riseth in the Horizon of any Place, be it *Naples* or any where else, he is the Space of the Earth's Semidiameter more distant from that Place than in his Meridian at Noon. Now there being but an inconsiderable Proportion between the Depth of the lowest Valley in the World and the Semidiameter of the Earth, which is near 4000 Miles, it follows, that the Sun must be 3000 Miles and upward nearer at Noon than at his rising, there being no Valley the tenth part of 1000 Miles deep.

Paradox 20. There is a certain Village in the South of *Great Britain*, to whoſe Inhabitants the Body of the Sun is leſs viſible about the Winter Solſtice than to thoſe who reſide on the Iſlands of *Iceland*.

Solution. 'Tis very poſſible that there may be one or more Villages, not only in the South of *England*, and particularly in *Suſſex*, but in a more Southern Latitude, ſo ſituated on the North-ſide of a Hill whoſe Height may intercept the Sun ſeveral Days before and after the Winter Solſtice from the Inhabitants of that Village.

Paradox 21. There is a vaſt Country in *Ethiopia Superior*, to whoſe Inhabitants the Body of the Moon doth always appear to be moſt enlightened when ſhe is leaſt enlightened, and to be the leaſt when moſt.

Solution. The Light that falls upon any Body being always in a reciprocal duplicate Ratio of the Diſtance from the luminous Body, it follows, that not only in *Ethiopia*, but in all Parts of the World, the Moon doth always appear to be moſt enlightened at the Full Moon when ſhe is leaſt enlightened, becauſe ſhe is then removed from the Sun farther than at New Moon, by the Diameter of the Moon's Orbit.

Paradox 22. Thereis a certain Iſland, whereof mention is made by ſeveral of our lateſt Geographers, whoſe Inhabitants cannot properly be reckoned either Male or Female, nor altogether Hermaphrodites; yet ſuch is their peculiar Quality that they are ſeldom liable either to Hunger or Thirſt, Cold or Heat, Joy or Sorrow, Hopes or Fears, or any ſuch of the common Attendants of human Life.

Solution. Trees or Shrubs growing on an Iſland not inhabited by Animals or Puppets, may be called Inhabitants, either will anſwer this Paradox.

Paradox 23. There is a remarkable Place of the Earth, of a conſiderable Southern Latitude, from whoſe Meridian the Sun removeth not for ſeveral Days at a certain time of the Year.

Solution. Under the South Pole, or within the Artic Circle, the Sun enlightens the Meridian by ſhining conſtantly upon it for 30 Days together.

Paradox 24. There is a certain Place of the Earth, of a conſiderable Northern Latitude, where tho' the Days and Nights, even when ſhorteſt, do conſiſt of ſeveral Hours, yet in that Place 'tis Mid-Day or Noon every Quarter of an Hour.

Solution. Under the North Pole.

Paradox 25. There are divers Places on the Globe of the Earth, where the Sun and Moon and all the Planets do actually riſe and ſet according to their various Motions, but never any of the fixed Stars.

Solution. Under the Poles the Planets, by their Motions, get North or South Declination, conſequently riſe and ſet with relation to thoſe two Places: but the fixed Stars keeping an exact Diſtance from the Pole may be ſaid never to riſe or ſet.

Paradox 26. There is a remarkable Place on the Terraqueous Globe, where all the Planets, notwithſtanding their different Motions and various Aſpects, do always bear on one and the ſame Point of the Compaſs.

Solution. Under either of the Poles of the World.

Paradox 27. There is a certain noted Part of the Earth, where the Sun and Moon, tho' it be the very inſtant of Time the Moon is at full, yet they may both happen to riſe at the ſame inſtant of Time and upon the ſame Point of the Compaſs.

Solution. Under the North Pole, the Sun and Full Moon, both decreaſing in South Declination and Latitude, will riſe in the equinoctial Points at

the ſame Moment, and under the North Pole there is no other Point of the Compaſs but South.

Paradox 28. There is a certain Place on the Continent of *Europe*, where if ſeveral of the ableſt Aſtronomers the World now affords ſhould nicely obſerve the Celeſtial Bodies, and that at the ſame inſtant of Time, yet the Planetary Phaſes, and their various Aſpects, would be really different to each of them.

Solution. Neither at the Center, or any part of the Earth, no one can obſerve all the Celeſtial Bodies at one and the ſame inſtant of Time, and conſequently will appear different, becauſe they are conſtantly in Motion.

Paradox 29. There is a large and famous City on the Continent of *Africa*, many of whoſe Inhabitants are born perfectly deaf, and others ſtone-blind, and continue ſo during their whole Lives; and ſuch is the amazing Faculty of thoſe Perſons that the Deaf are as capable to judge of Sounds as thoſe that hear, and the Blind of Colours as they who ſee.

Solution. The Blind and Deaf have Capacity to judge of Colours as they who ſee and hear, though they want the Senſes of Seeing and Hearing.

Paradox 30. There is a certain People in South *America* who are properly furniſhed with only one of the five Senſes, *viz.* that of Touching, and yet they can both hear and ſee, taſte and ſmell, and that as nicely as we *Europeans* who have all Five.

Solution. All the Senſes are properly by the Touch; in ſeeing, the Object touches the Retina; hearing, the Sound touches the Drum of the Ear; ſmelling, the Effluvia touch the Senſorium; taſting, the Palate, *&c.*

Paradox 31. There is a certain Country in South *America*, many of whoſe ſavage Inhabitants are ſuch unheard of Cannibals, that they not only feed

upon

upon human Flesh, but some of them do actually eat themselves, and yet they commonly survive that strange Repast.

Solution. The mystery of this Paradox depends only on the Word themselves; for if they don't eat their Meat themselves no Body can eat for them so as to sustain their Life.

Paradox 32. There is a remarkable River on the Continent of *Europe*, over which there is a Bridge of such a Breadth that above 3000 Men may pass a long upon the same a-breast; and that without crowding one another in the least.

Solution. There are several places in *England*, and other parts, where Rivers run a considerable Way under Ground; as the *Guadiana* in *Spain*, and the Mole in *Surrey*; the latter runs from *Darking* to *Leatherhead* under Ground, being upwards of four measured Miles, are more than 7000 Yards which will allow near seven feet to each Man, in Breadth, to walk if there were 3000 Men to march a-breast.

Paradox 33. There is a large and spacious Plain in a certain Country of *Asia*, able to contain 6000 Men drawn up in Battle Array, which number of Men being actually brought thither and there drawn up, it were absolutely impossible for any more than any one single Person to stand upright upon the said Plain.

Solution. By the 13 E. 3 of Euclid, a Plain can touch a Sphere only in one Point called the Contact, and that Person only who stands on that Point with respect to the Center of the Sphere, can stand upright.

Paradox 34. There is a certain *European* City whose Buildings being generally of firm Stone, are for the most Part of a prodigious Height, and exceeding strong, and yet it is most certain, that the Walls of those Buildings are not parallel

to one another, nor perpendicular to the Plain on which they are built.

Solution. All Walls are endeavoured to be built perpendicular to the Tangent, and point to the Center of the Earth, where they, if continued, would meet in a Point, and consequently are not Parallels, and but in one Point only can a Perpendicular be raised on an horizontal Plain, as is evident from the Proposition in the preceding Paradox.

Paradox 35. There is a certain City in the Southern part of *China*, whose Inhabitants both Male and Female do observe almost the same Posture, and Gate in walking, as we *Europeans*, and yet they frequently appear to Strangers as if they walked on their Heads.

Solution. In *China* and all other places where the Inhabitants stand near the Sea, or any standing Water that is clear, Strangers, or others standing by them and looking on it, must see them as tho' their Heads were downward by the refracted Vision.

Paradox 36. There are ten places of the Earth distant from one another 300 Miles and upwards, and yet none of them have either Longitude or Latitude.

Solution. These ten places must be supposed to be in the Earth, and not upon it; for Longitude and Latitude are reckoned on the Surface of the Globe only; so the Axis of the Earth, or any other imaginary Line through it, being about 7200 Miles, will not only answer the Paradox, but if it had been said twenty four Places, it would have kept within the Possibility of the demand.

Paradox 37. There are two distinct places of the Earth, lying under the same Meridian, whose Difference of Latitude is sixty Degrees compleatly, and yet the true Distance between those two places doth not really surpass sixty *Italian* Miles.

Solution.

Solution. The two places are not meant on the Superficies of the Earth, as you may perceive by the Word of, and not upon; then the places will be so near the Center of the Earth, as two Lines supposed to come one from 0 Latitude, the other from 60° Latitude, and to meet in the Center, may approach within the Distance of 60 *Italian* Miles.

Paradox 38. There are also two distinct places of the Earth lying under the Equinoctial Line, whose Difference of Longitude is compleatly eighty six Degrees and a half; and yet the true Distance between those two places is not full eighty six *Italian* Miles.

Solution. The two Places, as in the foregoing Paradoxes, must be supposed to be within the Earth; and even at forty Miles Distance from it's Center, will sufficiently answer the Paradox.

Paradox 39. There are three distinct Places of the Earth, all differing both in Longitude and Latitude, and distant from one another 2000 Miles compleatly, and yet they all bear upon one, and the same Point of the Compass.

Solution. All places differing both in Longitude and Latitude, at what Distance soever with Respect to the Poles, bear upon the same Point of the Compass, or they may be in the same spiral Rhomb.

Paradox 40. There are three distinct places on the Continent of *Europe*, equidistant one from the other, they making a true equilateral Triangle, each of whose sides doth consist of a thousand Miles; and yet there is a fourth place so situated in respect of the other three, that a Man may travel on foot from it to any of the other three in the Space of one artificial Day, at a certain Time of the Year, and that without the least Hurry or Fatigue whatsoever.

Solution.

Solution. By an artificial Day is here meant from Sun riſing to Sun ſetting, and beyond the Tropics and nearer the Poles the Days are increaſed when the Sun comes on that ſide the Equator, from twenty four Hours to about a hundred Days long; ſo that there would not be a neceſſity of travelling above four Miles every twelve Hours; to compleat the Terms of the Paradox.

Paradox 41. There are three diſtinct places on the Continent of *Europe*, lying under the ſame Meridian, and at ſuch a Diſtance that the Latitude of the third, ſurpaſſeth that of the ſecond, ſo many Degrees and Minutes exactly, as the ſecond ſurpaſſeth the firſt, and yet the true Diſtance of the firſt and third from the ſecond, or intermediate place, is not the ſame by a great many Miles.

Solution. The Figure of the Earth being not exactly round, as is generally conceived, but what is termed by Geometricians an oblate Spheroid, which is the Shape of a Bowl, ſo that the Axis is ſhorter than the Diameter, conſequently will cauſe ſuch a Difference as expreſſed in the Paradox.

Paradox 42. There are two diſtinct places on the Continent of *Europe*, ſo ſituated in reſpect of one another, that tho' the firſt doth lie Eaſt from the ſecond, yet the ſecond is not Weſt from the firſt.

Solution. If the artificial Globe is placed in an oblique Poſition, then it will appear, tho' two places bear due Eaſt and Weſt from one another, yet meaſured by the Quadrant of Altitude, they will not anſwer to the true bearing as they are on the natural Globe.

Paradox 43. There is a certain *European* Iſland, the Northermoſt Part whereof doth frequently alter both it's Longitude and Latitude.

Solution. There are floating Iſlands in ſeveral Parts of the World, and whenever they are moved from

from one Place to another, not only the northern, but every Part alters in Longitude and Latitude.

Paradox 44. There is a certain place in the Iſland of *Great Britain*, where the Stars are always viſible at any time of the Day if the Horizon be not overcaſt.

Solution. In a deep Well or Coal-pit the ſurrounding Light which the Atmoſphere ſpreads in the open Air, does not preſs on the Sight; ſo that if the Shaft of the Well or Pit be ſtrait, and there be Stars in or near the Zenith after ſtedfaſtly looking up a Minute or two, you'll diſcover them; hence ſeveral Aſtronomers have had Wells for that purpoſe.

Paradox 45. It may be clearly demonſtrated by the Terreſtrial Globe that it is not above twenty four Hours ſailing from the River of *Thames* in *England*, to the City of *Meſſina* in *Sicily*, at a certain time of the Year, provided there be a briſk North Wind, a light Frigate, and an Azimuth Compaſs.

Solution. This is meant of the Artificial Globe, and Hour-Index.

CHAP. XXXV.

Of the three Parts of the Art of Navigation; and first of the Structure of a Ship

PROPOSITION I.

The Art of Navigation teaches how a Ship may be commodiously and safely brought from one place to another, thro' the Sea, by the Help of the Wind.

AND because the Situation of one Place with another is considered in this Part; this Doctrine is justly brought in here in the Comparative, or Relative, Part of Geography.

AND I think in this Art (that is so noble and useful to human Society) there are properly three Parts; 1. Of the Structure of a Ship; to which may be referred the Ship's Motion in the Water. 2. Of the Burden to be carried in the Ship. 3. The governing of the Ship, which is called, in general, the Art of Navigation, by way of Excellency; and is the chief Part thereof; the other two belonging principally to Mechanics and Statics; whereas the directing of the Ship depends wholly upon Geography.

PRO-

PROPOSITION II.

In building a Ship these things are to be considered.

1. THE Choice of the Wood or Matter that will last longest in the Sea; for which see *Vitruvius*, and other Authors: and here also is to be considered how the Wood is to be prepared, it's Density increased, and the useless Moisture taken away by Fire; and also defend from Corruption by covering with Pitch, *&c.* which Natural Philosophy teaches.

2. THAT such a Figure be given to the Ship which is fittest for Motion in the Sea, and requires the least Force to move it. To this belongs the different Shapes of the antient and modern Ships, wherein several things worthy to be known may be produced from Antiquity and modern Inventions; and several things proposed from Staticks and Phoronomics, concerning the Motion of Bodies of different Figures; especially what the divine *Archimedes* hath left us of the Motion of Bodies in Water: but seeing few delight in such things, and our Design is only to give a Compendium of general Geography, I thought fit to omit the Explication of these things, and to enumerate only the Heads and Parts of that Doctrine: which I shall also do in what follows. And if we shall understand that these things are acceptable to Youth, we shall add them in another Edition, fully explained; and other things likewise, to the preceding Chapters.

BUT to return; a good Shape is a great Matter for moving easily and swiftly in the Water; and for this chiefly are Ships commended, especially in Sea-Fights: and there is a great Difference found among Ships in this particular;

but this depends on Statics, and the Laws of Motion.

3. IN the Structure of a Ship, it's Figure is to be ſuch as that it may be eaſily defended againſt Storms and Waves, that it may not be overſet; but of this more in the ſecond Part, of the Ship's Burden. This alſo belongs to Statics, and the Motion of Fluids, as Air or Water.

4. THE bigneſs a Ship is to be conſidered; where ſeveral things may be advanced by comparing Antiquity with the preſent Time. The Ship *Alexandrina*, made by the Command of *Hiero*, King of *Sicily*, and ſent as a Preſent to *Ptolemy*, King of *Egypt*, *Archimedes* being the Builder, was thought to be twelve thouſand Tun; and *Callixenus* writes, that *Philopator*'s Ship was two hundred eighty Cubits long, thirty eight broad, and forty eight high. The biggeſt ſhips at preſent are thoſe of the *Spaniards* and *Portugueſe*, which they call *Caracs*, which carry One thouſand and more *Vehes*, or Laſts, as the *Germans* call them; each being twelve Tun. The *Dutch* Ships do not carry above ſeven hundred Laſts (*f*).

5. THERE belongs chiefly to the Structure of a Ship, the Knowledge of the building of the Keel, the Rudder, the Ribs, the Stern, and Fore-part, the Maſts, the Sails, the Cables, the Anchors; of which not only the Matter, Figure, and Conſiſtency, but alſo their Bulk and Weight is to be conſidered.

(*f*) Here ſeems to be ſome conſiderable Miſtake about the Burden of Ships; for by *Dolia*, or Tuns, the Author expreſsly declares, that he means twenty hundred Weight. See *Chap*. xxxiv. *Prop*. 1. But the largeſt Ships of Burthen in *England* and *Holland* ſeldom exceed ſix or ſeven hundred Tun. See alſo *Prop*. 8. of the next Chapter.

6. TO

6. TO this alſo belongs the Knowledge of helping the Fractures, or other Faults of a Ship, by which too much Water is let in.

FOR which purpoſe 'tis uſual in ſailing, to take a Ship-Carpenter along with them.

AND ſo much for the firſt Part of Navigation; *viz.* the Art of Ship-building; which we have but briefly touched upon.

CHAP. XXXVI.

Of a Ship's Burden; which is the second Part in Navigation.

PROPOSITION I.

The Burden of a Ship is expressed by Lasts or Tuns.

A Ship's Tun is two thousand Pound Weight, and a Last twelve Tun, or twenty four thousand Pound Weight.

PROPOSITION II.

All Bodies, that are lighter than Water, appear in some Measure above the Water, floating on it; but if heavier, they sink; and if of equal Weight, they keep any Place that is given in it.

TO this belongs the Knowledge of the different Weights of different Bodies, as Lead, Gold, Iron, Wheat, Sand, Oil, Wine, whose Weights may be compared with that of Water.

COROLLARY.

FROM this it appears, that the Weight of the Ship, and it's Burden, must be less than the Weight of as much Water, as is equal to the Solidity

lidity or Capacity of the whole Ship. *See Prop.* vi. *following.*

PROPOSITION III.

The nearer a Ship comes to a cubic Figure, that is of equal Length, Breadth, and Thickneſs, it will bear the greater Weight.

THE Demonſtration of this is derived from the Doctrine of Statics.

PROPOSITION IV.

Two things are to be regarded in loading of a Ship; 1. Not to load her ſo far as that the Burden, with the Ship's Weight, be equal to, or greater than, a Bulk of Water, equal to the Capacity of the Ship, or it's Solidity, tho' it muſt not be much leſs, or elſe there muſt be Ballaſt added. 2. The Depth of the Waters thro' which the Ship is to ſail muſt be conſidered.

FOR tho' the Weight of the Water will admit the Weight of a Ship, and it's Burden when it's Weight is leſs than the Water of an equal Bulk with the Ship; yet if the Water have a leſs Depth than the Quantity of the Ship, under the Superficies of the Water, the Ship will touch the Ground, and ſtop there. And therefore the *Spaniards* put a greater Burden on their Ships than the *Dutch*, becauſe their Points and Shores are deeper; and ſo bigger Ships can go to *Zeeland* than to *Holland.*

PROPOSITION V.

If a Ship be so loaded that it's Weight be nearly equal to the Weight of the Sea Water, of an equal Bulk with the Ship, it will not sink; but when it comes to a River it will.

THE Cause is, that River Water is lighter than Sea Water; if therefore the Weight of a loaded Ship be nearly equal to the same Bulk of Sea Water, it will be greater than the same Quantity of River Water; and therefore the Ship sinks. And thus have many Ships been sunk, thro' the unskillfulness of those that loaded them; and by not being unloaded before they come to the River. What the Burden should be, may be known from the Proportion of the Sea Water to River Water, as in *Prop.* 8.

PROPOSITION VI.

Any Body swimming in Water hath the same Weight as Water of an equal Bulk with the Part under Water.

COROLLARY.

HAVING the Quantity of the Ship under Water, you may find the Weight of the Ship, and it's Burden; for the Weight of the Water is, or may easily be known. For example; Suppose a cubical Foot of Water to be seventy Pounds, and if the Part of the Ship under Water be two thousand cubical Feet, then the Water equal to the Part of the Ship under Water will be one hundred and forty thousand Pound; and so much should the Weight of the Ship and Cargo be.

PROPOSITION VII.

If a Body be placed in Waters of different Weights, the Part immersed in the lighter Water, hath that proportion to the Part immersed in the heavier, that the Weight of the heavier Water hath to that of the lighter.

PROPOSITION VIII.

A Ship is generally allowed to bear such a Burden as is equal to the Weight of one half of the Bulk of Water, that the Ship can contain.

SUPPOSE a Ship contain 500.000 Tun, each being 2000 Pound; that is, if it contain 1.000.000.000 Pound, it will bear 250.000 Tun, or 500.000.000 Pound. And thus we are to understand them, when they say, a Ship is of such a Burden.

THE *Spanish* Caracs carry twelve hundred Lasts; but the largest *Dutch East-India* Ships not above eight hundred.

PROPOSITION IX.

The greater the Ship's Burden is, the less the Ship is tossed by Storms: a Ship of two thousand Tun can bear a Storm that will damage a Ship of three hundred, or seven hundred Tun.

MORE might be added here of lessening a Ship's Burden, and of the different Weight in the Stern, Fore-part, or Middle; and of raising a Ship that is sunk, *&c.* but being upon this Subject it may not be amiss to subjoin the following Directions, how, by having the Dimensions of a Ship

given, to find her Tunnage, or Burthen, and the general Rule amongst the Ship-Wrights about *London*, is to multiply the Length by the Keel by the Breadth at the Mid-Ship's Beam, and that product by half the Breadth at the Beam, the last product, divided by 94, will give, in the Quotient, the Burthen of the Ship.

Example.

SUPPOSE a Ship 72 Foot by the Keel, and 24 Foot by the Beam; what is the Tunnage or Burthen of the Ship.

Keel——72
Beam——24
288
144
1728
Half the Breadth — 12
Divided by —— 94)20736(220 $\frac{56}{94}$
193
56

THE Ship's Burthen is 220 Tuns and more than one half.

THERE is another Method of finding the Tunnage, by having the Length by the Keel, the Breadth by the Beam, and the Depth in the Hold, given to find the Burthen; but as the Breadth at the Beam in Ships of Burthen is nearly proportionable to the Depth in the Hold, we shall at present content our selves with the Method above, as being the most expeditious and true, as well as the most commonly used.

CHAP. XXXVII.

Of the third and chief Part of the Art of Navigation, which consists in directing and governing a Ship; and the Sub-division of it into four Parts.

PROPOSITION I.

This Art consists in governing and directing a Ship to such a Point (in whatever Part of the Sea it is) as will bring it to the designed Port without Danger.

THERE are four Parts therein; 1. Special Geography, or the Knowledge of the Space between the two Places, and of it's Properties. 2. The Knowledge of the Points they lie in from one another, at any time. 3. The Knowledge of the Way thro' which the Ship is to be brought to the Place designed; for there are between every two Places an infinite Number of Lines. 4. The Knowledge of the Situation of each Place come to; and how it lies from the Place designed.

THIS is the chief Art of guiding a Ship.

PROPO-

PROPOSITION II.

The Knowledge of the intermediate Space comprehends the following Particulars.

1. A Knowledge of the Situation of Lands, and their running out into the Sea; the winding of Shores, of Promontories, Mountains, Bays, and Sand-Banks; the depth of the Water of Streights, Islands, and the certain Marks of each Shore, or part of the Sea; and the Aspect that Lands on the Shores have at such and such Places; and the depressing or rising of the Shore: which are found from special Geography, and Sea-Charts; but most easily by Practice in sailing oft to such Places; for which reason some are fitter to guide a Ship to one Place than another.

2. THE Knowledge of the general and special Winds, and the proper and stated Winds in a Place, which is chiefly necessary in sailing in the *Torrid Zone*, and Places near it; for here the general Winds, and in many Places the anniversary Winds, called *Monsoons*, prevail; and either hinder or forward the Voyage; for the *Indian* Sea is sailed with such Winds. We spoke largely hereof in *Chap.* 20. and of the stated Storms and Signs thereof: all which the Master of the Ship should know; and we gave an Example of the Loss sustained for want of Knowledge therein, in the same Chapter.

3. THE Knowledge of the Points that the Sea and Waves are carried to, and carry the Ship with them, which differ in many Places, as in *Chap.* xvii, especially the Knowledge of the Flowing and Ebbing of the Sea, is requisite, and the time when

it

it begins to riſe and fall every Day; for without this a Ship is in great danger near the Shores and Sand-Banks, moſt of which hinder a Ship's Courſe at low Water, which they do not at high Water: and ſailing is alſo eaſier towards Land, at the Flowing, and more difficult at Ebbing. We touched upon the Ebbing and Flowing of the Sea in a *Prop.* of *Chap.* xiv. but in ſome Caſes a more accurate Knowledge is requiſite as to the true cauſe of the ebbing and flowing of the Sea; and the Knowledge of this being of ſuch great uſe towards the forming a juſt Idea of the General Theory of the Tides, as to it's various Motions, and other Accidents and Circumſtances that attend it: I ſhall here ſubjoin

Of the General Motion of the Tides, and the true Cauſe of the Flowing and Ebbing of the Sea.

VARIOUS have been the Conjectures of different Authors, with reſpect to the Tides, ſome of which are liable to Contradiction from the very firſt Principles of Aſtronomy as hinted in the Note *(g)*, *Prop.* xii. *Chap.* xiv; nor can we in reaſon allow the Opinon that *Des Cartes* advances in *Prop.* xi, of the ſame Chapter; where he aſſigns the preſſure of the Moon's Orb upon the Water, or fluid part of this Terraqueous Globe, to be the Cauſe of the different Height of the Water, or as we call it high and low Water; for if we ſuppoſe this, theſe two abſurdities would follow; Firſt, If the Tide was governed by that principle of the Preſſure of the Moon's Orb, it would naturally incline to be low Water where the Moon is vertical, or indeed in any part of the Meridian, and high Water when the Moon is in the Horizon, or furtheſt diſtant from the Meridian, but the contrary is evident, and it would naturally be high Water when the Moon

Moon is vertical; or any where in the Meridian and low Water, when horizontal, &c. except (as it commonly happens near the Coaſt) that the interjacent Land obſtruct or divert the natural Courſe of the Tide, and not only cauſe the high Water to happen at a time far different from that of the Moon's ſouthing, but cauſe the Flood to ſet upon a different Point than to the weſtward; though if the Tide did not meet with thoſe Impediments, and other Accidents, it would not be liable to thoſe Mutations, or Alterations, either in point of Time or Motion. See *Chap.* xiv. *Prop.* vii. and *Prop.* xviii. *Secondly*, If the Fluctuation of the Tides be occaſioned by the Preſſure of the Moon's Orb; or, in other words, if her centrifugal Force, if it may be ſo called, be ſuch, that the Extremity of her Orb be able to depreſs the Water, or fluid part of this terraqueous Globe, at ſo great a diſtance as the Earth is from the Moon; and if we allow that undeniable Maxim in Philoſophy, that *the nearer the Cauſe the ſtronger the Effect*; it would follow, that That Principle that could repel or depreſs the Waters at the diſtance of this Earth, would ſeparate the Moon into an infinite number of Atoms; and the particles of Matter of which ſhe conſiſts, would be diffuſed and diſ-united by that very principle, the contrary of which (*viz.* centripetal Force, or a natural Tendency to her Center) keeps her together; but if we allow the Moon to act upon all Fluids that are within the Orb of her Attraction, or, which is the ſame, her Gravitation towards her Center, and that this Influence extends to the Earth, ſo far as to act viſibly upon the fluid part of the Water, which common Experience proves, it will neceſſarily follow, that the Sea will have a natural, tho' weak, tendency towards the Moon, and that, as above aſſerted, it would be high Water where the Moon is vertical, or ſome where in the

the Meridian if no Obſtructions or Accidents interpoſed.

AND for a further experimental Proof of this, let us a little trace the obſerved Motion of the Tides, and we ſhall find room enough to conjecture, or rather be able to prove, that the true and natural Motion of the Tide is from Eaſt to Weſt; and that it would always be high Water when the Moon is upon the Meridian; if the Earth was all over covered with Water equally as deep as the Sea is in the deep parts of it; and that the Irregularity of the Tide is generally occaſioned by thoſe parts of the Earth that appear above the Surface of the Water, and intercept it's weſtern Motion; as for Inſtance,

AS the Sea has no viſible Paſſage between *Europe* and *Africa*, let us ſuppoſe them both to be one main Continent extending from 72 North to 34 South, the middle between theſe two would be in Latitude 19 Degrees north, near Cape Blanco upon the Weſt Coaſt of Africa; but it is impoſſible that the flood Tide ſhould ſet to the weſtward upon the Weſt Coaſt of *Africa* becauſe the main Continent for above fifty Degrees North, and as much South, bounds that Sea on the Eaſt, and therefore if any regular Tide, as proceeding from the Motion of the Sea, from Eaſt to Weſt, ſhould reach this place, it muſt either come from the North Cape Southward, or from the *Cape* of *Good Hope*, or the South Cape of *Africa*, to the Northward, to the aſſigned Latitude upon the Weſt Coaſt of *Africa*.

THIS Opinion is further corroborated, or rather fully confirmed, by common Experience, that the flood Tide ſets to the Southward along the Weſt Coaſt of *Norway*, from the North Cape to the *Naze*, or Entrance of the *Baltic* Sea, and ſo proceeds to the Southward along the Eaſt Coaſt

of

of *Great Britain*, and in it's passage supplies all those Ports with the Tide one after another, the Coast of *Scotland* having the Tide first, because it proceeds from the Northward to the Southward; and thus on the Days of the Full or Change, it is high Water at three Quarters past 12, but at *Tinmouth-Bar*, the same Day not till 3. From thence rolling to the Southward it makes high Water at the *Spurn* a little after 5, (but not till 6 at *Hull*, by reason of the time required for it's passage up the River) from thence passing over the *Wells* into *Yarmouth* Road, it makes high Water in *Yarmouth* Road a little after 8, but in the *Pier*, not till 9, and it requires near an Hour more to make high Water at *Yarmouth* Town; in the mean time setting away to the Southward, it makes high Water at *Harwich* at half an Hour after 10, at the *Nore* at 12; at *Gravesend* half an Hour past 1, and at *London* at 3, all in the same Day; and although this would seem to contradict that Hypothesis, of the natural Motion of the Tide being from East to West, yet as no Tide can flow West from the main Continent of *Norway*, or *Holland*, or out of the *Baltic*, which is surrounded by the main Continent, except at it's Entrance, it is evident, that the Tide we have now been tracing by it's several Stages from *Scotland* to *London*, is supplied by the Tide whose original Motion is from East to West; yet as Water always inclines to the level, it will in it's passage fall towards any other Point of the Compass, to fill up vacancies where it finds them, and yet not thereby contradict but rather confirm the first Hypothesis.

WHILE the Tide or high Water is thus gliding to the Southward along the East Coast of *England*, it also sets to the Southward along the West Coast of *Scotland* and *Ireland*; and coming about to the South part of *Ireland*, a Branch of

of it falls into *St George*'s Channel, the Flood running up North-East, as may be naturally inferred from it's being high Water at *Waterford*, above three Hours before it is high Water at *Dublin*, or thereabout on that Coast, and it is three quarters of an hour Ebb at *Dublin* before it is high Water at the Isle of *Man*, &c.

BUT not to proceed further in particulars than our own, or the *British* Channel, we find the Tide sets to the Southward from the Coast of *Ireland*, and in it's passage a Branch of it falls into the *British* Channel between the *Lizard* and *Ushant*; it's progress to the Southward may be easily proved, by it's being high Water on the Day of the Full or Change at *Cape Clear* after 4; and at the *Ushant* about two Hours after, *viz.* at six, and at the *Lizard* after seven, the *Lizard* and the *Ushant* may properly be called the Chaps of the *British* Channel, between which the Flood sets to the Eastward, along the Coast of *England* and *France*, till it comes to the *Goodwin*, or the *Galloper*, where it meets the Tide before mentioned, which sets to the Southward, along the Coast of *England*, to the *Thames*, where it may not be amiss to observe that these two Tides meeting, contribute very much towards the sending a powerful Tide up the *Thames*, to the City of *London*: and, by the bye, when the natural Course of the Tide is interrupted by a sudden Shift of the Wind; and between this Northern and Southern Tide, driving one back, and the other in, has been known to occasion two high Waters in three or four Hours, which by those who did not consider this natural Cause was looked upon as a Prodigy.

BUT now it may be objected, that this Course of the Flood Tide, East or East-North-East, up the Channel is quite contrary to the Hypothesis of the general Motion of the Tides being from East

East to West, and consequently of it's being high Water where the Moon is vertical, or any where else in the Meridian.

I answer; this particular direction of any Branch of the Tide doth not at all contradict the general Direction of the whole, a River whose Course is West may supply Canals which may wind North, South, or even East, and yet the River keep it's natural Course; and if the River ebb and flow, the Canals supplied by it would do the same, but not keep exact time with the River, because it would be Flood and the River advanced to some height, before the Flood reach the further part of the Canals, and the more remote the longer time it would require; and I may add, that if it was high Water in the River, just when the Moon is upon the Meridian, she would be far past it, before it could be high Water in the remotest part of those Canals or Ditches, and the Flood would set according to the Course of those Canals that received it, and could not set West up a Canal of a different Position, and as *St George's* Channel, the *British* Channel, *&c.* is no more in Proportion to the vast Ocean, than these Canals are to a large Navigable River; it will evidently follow, that among those Obstructions, and Confinements, the Flood may set upon any other Point of the Compass as well as West, and may make high Water at any other time, as well as when the Moon is upon the Meridian, and yet no way contradict the general Theory of the Tide before asserted.

FROM this Principle, as confirmed by the strict Observation of Mariners, the following Tide-Table is formed, to shew, at all the places therein mentioned, how many Hours and Minutes the Moon has past the Meridian when it is high Water at the said place, and consequently by knowing the

the time of the Moon's Southing, the time of the Day, that High-water happens at the same place may also be known.

A TIDE-TABLE.

	H.	M.	
A			
ABerdeen	0	45	S by W
Army	1	30	S S W
St Andrews	2	15	S W by S
Amsterdam	3	0	S W
Armentiers	3	0	S W
Aberwark			
Abroth	5	15	W S W.
Antwerp	6	0	W.
Abermoric	6	0	W.
Archangel	6	0	W.
Abermorith	6	0	W.
Amazons River in South America	6	0	W.
Aldborough	9	45	N W by N
B			
Beach	0	0	N and S
Blacktail	0	0	N and S
Race of Blanquet	0	0	N and S
Bajador in Barbary	0	0	N and S
Blacktail Beacon	0	0	N and S
Beachy	0	45	S by W
Blackness	1	30	S S W
Bluet	1	30	S S W
Bell-Isle	1	30	S S W
Berwick	1	30	S S W.
Bluet without	2	15	S W by S
Biscay coast	3	0	S W
Bourdeaux River Entrance	3	0	S W

	H	M.	
Buchaneſs	3	0	S W
Bona Eſperance	3	0	S W
Breſt	3	45	S W by W
Baſs without	3	45	S W by W
Bridlington	3	45	S W by W
Bourdeaux River within	3	45	S W by W
Brovage without	3	45	S W by W
Blois	4	30	W S W
Baltimore	4	30	W S W
Bree Sound	4	30	W S W
Bremen	6	0	W.
Blackney	6	0	W.
Briſtol River	6	0	W.
Briſtol Key	6	45	W by N
Bridgwater	7	30	W N W
Cape Blanco	9	45	N W by N
Bologne	10	30	N N W

C

Cape Cautin in Barbary	0	0	N and S
Condado	0	0	N and S
Chamber of Rye	0	45	S by W
Calais without	1	30	S S W
Camfere	1	30	S S W
Cocquet Iſland	3	0	S W
Cork in Ireland	4	30	W S W
Calais	4	30	W S W
Cape Clear in Ireland	4	30	W S W
Caldy	5	15	W by S
Caernarvan Bay	5	15	W by S
Cromer	6	0	W.
Concalo	6	0	W.
Caſkets without	8	15	N W by W
Cape Serra Leone in Guinea	8	15	N W by W
Cateneſs	9	0	N W

	H.	M.	
Chamberness	9	45	N W by N
Cowes	10	30	N N W
Caen in the Foss	10	30	N N W
Calais Road	10	30	N N W
Calshot	11	15	N by W
Condado	12	0	N and S

D

Dunkirk	0	0	N and S
Dover Port	0	0	N and S
Port Desire in America	0	0	N and S
Downs in the Road	2	15	S S W
Dundee	2	15	S W by S
Denbeigh	2	15	S W by S
Dort	3	0	S W
Dunbar	4	30	W S W
Dungarven	4	30	W S W
Dartmouth	5	15	W by S
St Davids Head	6	0	W.
Dublin in Ireland	8	15	N W by W
Dungeness	9	45	N W by N
Dunnose	9	45	N W by N
Diepe	9	45	N W by N
Dunwich	9	45	N W by N
Dover without	1	30	N N W

E

Emden	0	0	N and S
Eider	0	0	N and S
Elve	0	0	N and S
Enchuysen	0	0	N and S
Edam	1	30	S S W
Edinburgh	4	30	W S W
Exwater	4	30	W S W

	H.	M.	
Entrance of the Emes	7	30	W N W
Engomonts	9	0	N W
F			
Flanders Coaſt	0	0	N and S
Fluſhing	0	45	S by W
Before Fen in the Channel	1	30	S S W
Finmark Coaſt	1	30	S S W
Fountnay without	2	15	S W by S
Flanders without	3	0	S W
Flambrough Head	3	0	S W
Fair Iſle	3	0	S W
Frith	4	30	W S W
Falmouth	4	30	W S W
Forn	5	15	W by S
Foy	5	15	W by S
Foulneſs	6	45	W by N
The Fly	7	30	W N W
Frieſland Coaſt	7	30	W N W
Florida in Carolina	7	30	W N W
Fly without	8	15	N W by W
Foreland North and South	9	45	N W by N
Fair Iſle	11	15	N by W
G			
Gibralter	0	0	N and S
Graveling	0	0	N and S
Guernſey	0	45	S by W
Goree	1	30	S S W
Graveſend	1	30	S S W
Galicia	3	0	S W
Gaſcoign	3	0	S W
Groyn	3	0	S W
Gorend	11	15	N by W

Hever

H	H.	M.	
Hever	0	0	N and S
Hampton Key	0	0	N and S
Hern	0	0	N and S
Holy Island	1	30	S S W
Hartlepool	3	0	S W
Huntcliff-foot	3	45	S W by W
Humber without	4	30	W S W
Holmes	6	0	W.
Hull	6	0	W.
Hamburgh	6	0	W.
Hague	8	15	N W by W
Harlem	9	0	N W
Home-head	9	0	N W
Havre de Grace	9	0	N W
Harwich Banks without	10	30	N N W
St Helens	10	30	N N W
Harwich within	11	15	N by W
I			
Jutland Isles	0	0	N and S
Ireland West Coast	3	0	S W
Ireland South Coast	5	15	W by S
John de Luce	10	30	N N W
K			
Kentish Knock	0	0	N and S
Killiars	3	0	S W
Kingsale in Ireland	4	30	W S W
Kilduyn	7	30	W N W
Kildive	9	0	N W
L			
Lisbon	2	15	S W by S
St Lucas	2	15	S W by S
London	0	0	S W
Leith	4	30	W S W

	H.	M.	
Lawreneſs	5	30	W S W
Lynn without	4	15	W by S
Lundy Iſland	5	15	W by S
Lynn	6	0	W.
Lanion	6	45	W by N
Land's-end of England	7	30	W N W
Lizard	7	30	W N W
Lambay	8	15	N W by W
Lewſtoff	9	45	N W by N
Lenow	9	45	N W by N
M			
Maes within	0	45	S by W
Malden	0	45	S by W
St Mark	2	15	S W by S
St Matthew's point	3	45	S W by W
Mouſe-hole	4	30	W S W
Mounts Bay	4	30	W S W
Millford	5	15	W by S
Moonleſs	5	15	W by S
St Maloes	5	15	W by S
Magnes Sound	8	15	N W by W
Macknel's Caſtle	8	15	N W by W
Iſle of Man	9	0	N W
Margate Road	11	15	N by W
N			
Newport Iſle of Wight	0	0	N and S
Nore	0	0	N and S
North Cape	3	0	S W
Nantz River without	3	0	S W
Newcaſtle	5	15	W by S
St Nicholas Ruſſia	6	45	W by N
Needles	9	45	N W by N
Normandy Coaſt	10	30	N N W
Naze	11	15	N by W

O	H.	M.	
Orkneys	3	0	S W
Orwell	9	0	N W
Orfordness	9	45	N W by N
Orfordness without the Banks	10	30	N N W
Orfordness within the Sands	11	15	N by W
P			
Portsmouth	0	0	N and S
Poictou South Coast	3	0	S W
Pens	3	0	S W
Porthus	3	0	S W
Portugal Coast	3	0	S W
St Pauls in the Haven	6	0	W.
Plymouth	6	0	W.
Podesemsk in Russia	6	15	W by N
Thwart of Plymouth	7	30	W N W
Portland	8	15	N W by W
Peterport	8	15	N W by W
Picardy Coast	10	30	N N W
Q			
Queenborough	0	0	N and S
Quebec in Canada	6	0	W.
R			
Rebdan	0	45	S by W
Rochester	0	45	S by W
Romney	1	30	S S W
Ramkins	1	30	S S W
Robin Hood's Bay	3	0	S W
Rotterdam	3	0	S W
Rovain	3	45	S W by W
Rochel without	3	45	S W by W
Roan River within	3	45	S W by W
Ramsey	5	15	W by S

	H.	M.	
Rye	11	15	N by W
Rhodes	11	15	N by W
S			
Shooe	0	0	N and S
Along the Swin	0	0	N and S
Sheerneſs	0	0	N and S
Slevee	0	0	N and S
Southampton	0	0	N and S
Spits	0	0	N and S
Shotland	3	0	S W
Scilly	3	45	S W by W
Scarborough	3	45	S W by W
Sound	3	45	S W by W
Staples	3	45	S W by W
Severn	4	30	W S W
Seven Iſles	4	30	W S W
Stockton	5	15	W by S
Spurn	5	15	W by S
Salcomb	6	0	W.
Start	6	45	W by N
Sedmouth	6	45	W by N
Selberg	9	0	N W
Seven Cliffs	9	0	N W
Shoram	9	45	N W by N
Seyn-Head	10	30	N N W
Senegal	10	30	N N W
T			
Terveere within	0	45	S by W
Thanet Iſland	1	30	S S W
Terveere without	1	30	S S W
Tinmouth	3	0	S W
Tees Mouth	3	0	S W
Teneriff	3	0	S W
Torbay	5	15	W by S

Texel

	H.	M.	
Texel	7	30	W N W
Tergon	9	45	N W by N
U			
Urk	0	0	N and S
Use	3	0	S W
Vourd	4	30	W S W
Ushant without	6	0	W.
St Vallery	10	30	N N W
W			
Isle of Wight	0	0	N and S
Winchelsea	0	45	S by W
Weilands	1	30	S S W
Whitby	3	0	S W
Waterford in Ireland	4	30	W S W
Weymouth	6	0	W.
Wells	6	0	W.
Weymouth Key	6	45	W by N
Off the Isle of Wight	8	15	N W by W
Winterton	9	0	N W
Y			
Youghal in Ireland	4	30	W S W
Yarme	6	45	W by N
Yarmouth Road	8	15	N W by W
Yarmouth Pier	9	0	N W
Yarmouth Town	9	45	N W by N
Z			
Zealand Coast	1	30	S S W
Zuric Sea	3	0	S W

IN this Tide-Table, the first Column contains the Names of the Sea Ports; the second is the Hour and Minute of High-water, or the Days of the full and change at the Port, against which it

 stands,

ſtands, or the Hour and Minute to be added to the time of the Moon's ſouthing, to find the time of High-water at the ſaid Port. The third Column ſhews upon what point of the Compaſs the Moon makes full Sea, at the place againſt which it ſtands.

EXAMPLE.

I would know upon what Point of the Compaſs the Moon is, and what is the Hour of the Day, when it is High-water at *London* Bridge, on the Day of the full or change.

LOOK for *London* in the Tide-Table, and againſt it you find in the ſecond Column, 3 Hours 00 Minutes, and in the third Column S W; which ſhews that a South-Weſt Moon makes High-water at *London* Bridge, and that on the Days of the Full and Change it is High-water at *London* Bridge at 3 o'Clock. But for any other age of the Moon, add the Hour and Minute which ſtands againſt the Port, propoſed to the Hour and Minute of the Moon's ſouthing, their ſum (abating 12 if it exceeds) is the time of High-water next Morning, *&c.* of which hereafter.

Note. It is High-water when the Moon is upon both the oppoſite Points of the Compaſs; as if a South-Weſt Moon makes High-water at *London* Bridge, a North-Eaſt Moon will do the ſame; and if it is High-water at 3 in the Afternoon, it will be High-water at the ſame place at (near) 3 the next Morning alſo.

BUT as finding the time of High-water depends upon the Moon's ſouthing; and that is to be found by the Golden Number, and the Epact, it is neceſſary firſt to know how to find them as follows.

1. *To*

1. *To find the Golden Number.*

DIVIDE the Year of our Lord by 19, and the remainder with 1 added to it, is the Golden Number.

Example. I desire to know what is the Golden Number for the year 1734.

	19)1734(91
	24
Remainder —— ——	5
To which add — —	1
The Sum is the Golden Number —— —	6

2. *To find the Epact.*

MULTIPLY the Golden Number by 11, divide the Product by 30, the Remainder is the Epact. Or add 11 to the Epact of any one Year it gives the Epact for the Year following, casting away 30, if the Sum exceeds 30.

Example. What is the Epact for the year 1733.

The Golden Number is ————	5
Multiply by —— —— —— ——	11
The Product is — —— —— ——	55
From whence take — — —— ——	30
The Remainder is the Epact ———	25
The Epact for 1733 is ————	25
To which add —— —— — — ——	11
The Sum is — ————————	36
Cast away — — — — — — —	30
Remains the Epact for 1734, *viz.* —	6

3. *To*

3. *To find the Moon's Age.*

ADD the Epact, the Day of the Month, and the Number of the Month from *March* (accounting *March* 1, *April* 2, *&c.*) altogether, the Sum (casting away 30, if it exceed 30) is the Moon's Age.

Example. How many Days old is the Moon *June* 16, 1733.

The Epact in 1733 is — — —	25
June is the 4th from *March* —	4
The 16th Day ——— ——— ———	16
The Sum ——— ——— ——— ———	45
Cast away ——— ——— ——— —	30
Remains the Moon's Age —	15

4. *To find what Day the Moon Changes.*

ADD the Epact, and the Number of Months from *March* together, and substract the Sum from 30, but if the Sum amount to 30, or more, substract it from 60, the Remainder is the Day of the Moon's changing.

Example. I desire to know what Day of *June* in the Year 1733, the Moon will change.

THE Number of the Month from *March* Inclusive is 4, the Epact is 25; the two added together make 29, which taken from 30 there remains 1, which shews that the Moon changes *June* 1, 1733.

5. *To find the Time of the Moons southing.*

MULTIPLY the Moon's Age by 4, and divide the Product by 5, the Quotient is the Hour

to

to which for every one that remains, add 12 Minutes, it gives the time of the Moon's southing.

Example. I desire to know what time the Moon souths, *June* 7, 1733. The Moon will be found by the Rule above, to be 6 Days old, on the 7th of *June*; multiply 6 by 4, it produces 24, which divided by 5 the Quotient is 4, and 4 remains, which shews that the Moon souths at 48 Minutes after 4 o'Clock that Day.

BUT there is another Method for finding the Moon's southing, which I have seen in a Book in *English*. The Author entitles it, *How to know the time of the Moon's coming to South, only by a sight of the Moon at any time of the Day or Night*; and the Method being so easy in Practice, and so mathematically true, as well as familiar to all Capacities; I thought it was not proper to omit it.

THIS way of finding the Moon's southing, is grounded upon this known and undeniable Truth, that the new Moon, or when she is with the Sun, souths at Noon; and consequently the Moon when at the full, or opposite to the Sun, souths at Midnight; when she is half full, or at what is called the Quarters, she souths at six o'Clock; in which we may observe, that when the West half of the Moon is light, she souths at six in the Evening; and when the East half is light, she souths at six in the Morning, when the light part of the Moon is separated from the dark part by a strait Line, or Diameter, drawn through her Center divides her into two equal parts.

THIS being premised, and there being, as above observed, twelve Hours difference, between the time of her southing at the Change, or new Moon, and that at the full Moon, the Author supposes the visible Semi-Surface of the Moon to be divided into twelve parts, equal parts upon the globular

globular Surface of the Moon, but unequal as they appear at the Earth (nearly) like the orthographic projection, and these Circles to be marked 1, 2, 3, 4, &c. to 12. (See *Fig.* A, *Plate* VIII.) reckoning from the Primitive on the West side of the Moon, coming to 6 in the Diameter, or Line, which crosses the Center of the Moon, and divides her in two equal parts, and ending at 12 on the East part of the Primitive: This done when you see the Moon partly illuminated, compare her with the Figure, and consider to which of the Circles, the light part may be imagined to extend, and the number or Figure upon that Circle, is the time of the Moon's southing.

Example. Suppose the shaded part of the Moon N 5 S W was enlightened, it shews that the Moon souths that Day at 5 o'Clock; and because the light part is on the West Side, the Moon souths at five in the Afternoon; but if all that part of the Moon had been light, that is light in the Figure *viz.* N E S 5, the Number 5 upon the Arch, would show that she souths at five o'Clock, but the light part being on the East Side, shews that she souths at five in the Morning.

6. *To find the Time of High-water.*

TO the Hour and Minute of the Moon's southing, add the Hour and Minute found in the Tide-Table against the Port proposed, the Sum is the time of High-water at the said Port, but if it exceeds 12 Hours, cast away 12, and the Remainder is the time of High-water next Morning.

Example. I desire to know the time of High-water at *London* Bridge on the 7th of *June* 1733 above mentioned.

The

	H.	M.
The Moon souths that Day at — — —	4	48
Time against *London* in the Tide Table	3	00
Sum is high Water at *London* Bridge	7	48

THUS much I thought was necessary to be inserted, not only as to the Theory of the Tides, and the original Cause of the flowing and ebbing of the Sea in general, but with respect to the actual Calculation of their Motions, and the determining the times of High-water at any Place proposed in particular, which being done, and before I quit this Subject of the Fluctuation of the Water in different parts of the World, it may not be amiss to observe, that some whose over Curiosity have led them into extreams, and they allowing the abovementioned Hypothesis of the Tide, to be agreeable to both Reason and Experience, as well as to the Principles of Philosophy, would strain it beyond it's bounds, and from some Principle of the same Nature, would account for the overflowing of the River *Nile*; but as that proceeds from a quite different Cause from that of the ebbing and flowing of the Sea, I presume it will be no unnecessary Digression to give the following true and natural Reasons for that too, (and the rather because it has formerly been looked upon as something supernatural, or as a sort of a Prodigy) that the industrious Enquirer may be informed on one hand, as well as their Mistakes may be rectified who would draw inferences from wrong Foundations on the other.

Of

Of the Natural Cause of the overflowing of the River Nile *in* Egypt.

TO go so far back towards the original, as to give a Natural or Philosophical Reason for the excessive Rains, at certain Seasons of the Year, near or between the Tropics, would take up more time and room, than this Treatise of General Geography will admit of; but Experience, grounded upon the most natural and philosophical Reasons, convinces us that there are almost perpetual Rains from *April* or *May*, till *July* or *August*, in places lying near or within the northern Tropic; and this being proved and allowed, it will not be difficult to account for the Annual overflowing of the River *Nile*, which rises in about fourteen or fifteen Degrees of North Latitude, or about nine Degrees to the Southward, of the Tropic of *Cancer*, and in it's Course to the Northward, it crosses the said Tropic before it comes to the *Mediterranean*, or *Levant*, which lies in above thirty Degrees of North Latitude, and as it is so large a River, and runs through the low Grounds of *Egypt*, it must be supplied by a great Confluence of Rivers, and receive all those heavy Rains that fall in, or near it's passage, and having no way to disgorge it self, till it empties it self into the *Levant*, it is no more difficult to account for it's overflowing the low Lands of *Egypt*, in it's passage through it than it is to account for a Land flood, after a sudden heavy Rain in England, or in any other place; this Consideration makes the overflowing of the *Nile*, so far from being a Wonder, that it would be a much greater Wonder, and more difficult or rather impossible to be accounted for, if all these excessive and durable Rains that fall in the *Nile*, and that from the adjacent Country descend

descend into it, could vent themselves without some visible way of being conveyed to the Sea, and the River *Nile* not be affected with it; but seeing the vast confluence of Water, proceeding from those excessive Rains, has no other vent but by the *Nile*, it will necessarily follow, that the *Nile* must overflow it's bounds at those rainy Seasons, and yet it's Inundation has no dependance upon the Moon, nor upon the natural Causes, above assigned, for the regular flowing and ebbing of the Sea.

CHAP. XXXVIII.

Of the Bearing of Places, or the Points they lie in, from one another.

PROPOSITION I.

To know in each Place the four Cardinal Points, and the intermediate ones.

THIS is the most necessary Problem in the whole Art of Navigation, for without it there is no directing a Ship; and the want of this very thing hindered the Antients from sailing far. And herein is the chief Difference between the antient and modern sailing; for the Antients had no certain Method to find the North and South Points at any time; and therefore durst not trust themselves into the wide Ocean; but only coasted along the Shores, that they might by some Signs know where they were.

THE Antients had two ways which are serviceable to the Moderns, for finding the North and South (or a meridian Line) from which the other Points are easily known; 1. By the Stars at Night, particularly the *Little Bear*, and the Star in it's Tail, called the *Pole-Star*; which was much famed with Antiquity, and served to show them the North, and thereby all the other Points; for turning their Face to it, the East was on the right, and the West on the left, and the South behind; and they had a Circle with the Points on it, and bringing the

the North and South Point, to the meridian Line, the other Points were seen at once.

BUT by Day they used the Sun rising or setting, as we shewed in *Chap.* xxviii.

2. ANOTHER Method they had was by knowing the Situation of the Shores, and of one Promontory from another; for when one Point was thus known, either from the Maps, or by Observation and Experieence, they could in sailing find the rest; but then they could not go far from the Shores, which directed them as to the Points: for they could not at all times use the Sun and Stars for that end.

3. A third Method they used, was by observing the Points they had run in; for knowing how they first directed the Ship, and how much they turned again, their Course from that Point, they knew the other Points.

FROM whence the Reason appears of their imperfect and dangerous sailing; *viz.* their not knowing the Points in the wide Ocean, so as to tell how to steer.

THIS third Method by observing the Ship's Course, is of no use when the Ship is turned to a great many Points by the raging Sea and Waves.

SO far of their Method of finding the Meridian Line, which was so imperfect, that they durst never trust themselves in the vast Ocean, and so never knew *America*.

WE have now a plain and easy Method of finding the North and South Points, and all the rest from them, by the help of that wonderful Property which the Load-stone, and all Needles of Iron touched with it's Poles, or lying long near it, or even lying long in the Meridian Line, are found to have; which is, that they turn to the North and South, if not hindered; the Load-stone

 having

having two opposite Poles, of which the one turns always to the North, the other to the South, and the other Parts to the other Points; but the North and South Pole of it is only considered: and the same Property it communicates to a Rod of massy Iron, or a small Needle, but in a contrary way; for the end of the Needle drawn on the North Pole of the Load-stone, turns to the South; and that end which is applied or rubbed on the South Pole of the Load-stone, turns to the North, and is called the North Pole of the Needle: which wonderful Property of the Load-stone was unknown to the Antients, though, which is strange, they were acquainted with it's other Property of drawing Iron to it.

THUS the North and South Points may be easily found by hanging the Load-stone, which is carried to Sea with them, by a Thread, that it may turn itself easily to the North and South; but 'tis better done by applying a Needle to the North Pole of the Load-stone: for recovering it's Virtue, and drilling a Cap in it's middle, and laying it on the Top of a sharp brass Pin, so that it may move freely, it will, when it rests, show the North and South.

PROPOSITION II.

To make the Sea Compass.

DIVIDE a Circle drawn on a Chart into thirty two Points, and chuse one of them for the North, mark it with the *Flower-de-Luce*, and count the other Points from it, which are to be marked on it.

THEN let the magnetic Needle be fixed under the Circle drawn on the Chart, so as the middle of the Needle may be under the Center, and the North Pole on the Chart may be fixed to the North End

End of the Needle; then placing the Needle and Chart, fixed to it above, on the brafs Pin, that it may move freely, it will turn about, 'till the Needle lie in, or near, the Meridian Line. By the help of this Compafs they can go thro' the vaft Ocean to the moft remote Parts, being guided by the Direction of the Needle. We faid *near* the Meridian Line, for it doth not point exactly to it; for which fee *Prop.* vi, following.

PROPOSITION III.

Infinite Points may be drawn on the Compafs; Seamen count fixteen in fmall Voyages, and thirty two in greater, but fixty four in the greateft.

OF this we have fpoke in *Chap.* xx. whence may be had an accurate Explication. The *Portuguefe* call the Points *Rhombs.*

PROPOSITION IV.

The magnetic Needle (as alfo the Poles of the Loadftone itfelf) points direct North only in a few Places, but in moft Places declines a little to the Eaft or Weft, and that unequally; and fo doth not point due North and South.

FOR at one of the Ifles of the *Azores*, or *Flandrian* Ifles, called *el Corvo*, there is no Declination from the Meridian, and the Needle lies exactly in it; and 'tis fo in fome others, tho' not all Parts of that Meridian. In Places fituated eaftward from this Ifland to the Promontory of *Africa*, called *Cabo das Agulhas* (not far from the Cape of *Good-Hope*) the Needle declines eaftward unequally; fo that to the Ifles of *Triftan de Cunha*, and feventy Degrees further, the Declination increafes fo as to

be about thirteen Degrees there; and from thence it decreaſes all the way to Places near the Promontory of *das Agulhas*, in which there is again no Declination. And from that Place towards *India* the Declination begins to the weſtward. The Declination at *Hamburgh* is nine Degrees, at *Amſterdam* about five Degrees, tho' formerly it was more.

OBSERVATIONS teſtify, that the Declination is not always the ſame, but changes in proceſs of time. At *London* in 1580 it was found to be eleven Degrees fifteen Minutes; but in the Year 1622 it was only ſix Degrees thirteen Minutes; and in 1634 it was four Degrees ſix Minutes; Obſervations being made, both with old and new Needles. At *Paris* in 1640 it was three Degrees, and in 1610 it was eight Degrees, and the ſame is obſerved in other Places.

BEFORE the Variation of the Compaſs was obſerved to alter, or be different at the ſame place at different Times; it was ſuppoſed, by ſome, that the general Poſition of the Needle, towards the North and South, and yet not exactly to theſe points in all Places, or rather in but few places, was occaſioned by the *Excavations of ſome parts of this terraqueous Globe*; or by *magnetical Veins, collaterally reſpecting the Needle*, &c. But this Opinion was ſoon exploded, when the Variation of Variation was diſcovered; for if the poſition of the Compaſs (whether directly North and South, or with ſome deviation from the Meridian, which is called the Variation) had been always the ſame in the ſame place, there would be room to believe that That poſition of the Compaſs, was occaſioned by thoſe Excavations or Adamantine Rocks, *&c.* but as we find the Variation alters, there muſt be ſome other Reaſons aſſigned for the different Poſition or direction of the magnetical Needle. But as a Principle

to

to go upon, I ſhall rank ſome authentic Obſervations, of the Variation of the Compaſs in their proper Order, with the time when they were taken, and from thence prove the probability of the Variation of the Compaſs (however irregular it may ſeem) being reducible to a regular Motion.

		D.	M.	
1580	At *Limehouſe*, *London* — -	11	17	Eaſt
1622	At *London* —— ——	6	13	Eaſt
1634	At *London* — — ——	4	6	Eaſt
1640	At *Paris* — — ——	3	0	Eaſt
1666	At *London* —— ——	0	34	Weſt
1670	At *Batterſey* near *London* -	2	6	Weſt
1701	In the Channel — ——	7	30	Weſt

AND to this may be added, that at the writing here of *Anno* 1734, the Variation at *London*, is more than one Point weſterly.

I have inſerted this Catalogue of Obſervations of the Variation of the Compaſs, to prove that the Variation alters, and not only ſo, but in a ſort of a regular Manner too, as having been above eleven Degrees eaſterly in the Year 1580, and then gradually decreaſing to ſix, four, three, *&c.* and doubtleſs ſome time between the Year 1640, and the Year 1666 there was no Variaton; becauſe in 1666 the Variation was weſterly, increaſing to two, ſeven, and now above twelve Degrees; how far it may advance further that way, before it come at it's Period, Time only can determine; nor are we certain what was it's utmoſt limits eaſterly before the aforeſaid Year 1580, or when it was at thoſe limits; but certain it is that this regular Motion of the Variation, as obſerved, corroborates, or rather confirms, that excellent Theory,

of the celebrated Dr *Halley* as to magnetical Poles, *&c.* hereunto subjoined (*e*).

PRO.

(*e*) The learned Dr *Halley* having made a Collection of the exactest Observations he could procure, and carefully compared and considered them together; thence deduces the following Conclusions, concerning the Variation of the *magnetical Needle*, See *Philos. Transact.* No. 148.

1. That in the Year 1683, the Variation was to the West over all *Europe*; but more in the eastern Parts than the western.

2. That on the Coast of *America*, about *Virginia*, *New-England*, and *New-found-land*, the Variation is likewise westerly; and increases all the way to those that go northerly along the Coast: so as to amount to above twenty Degrees at *New-found-land*, nearly thirty in *Hudson*'s Streights, and fifty seven in *Baffin*'s Bay. But it diminishes to those that sail eastward from this Coast. And from these two Observations it seems to follow, that *there ought to be an easterly Variation*, or *at least not a westerly one, somewhere between* Europe *and the North Part of* America: and this we may conjecture happens about the most easterly of the *Tercera* Islands.

3. That on the Coast of *Brasil* there is an easterly Variation which increases considerably in sailing to the southward; so as to be twelve Degrees at Cape *Frio*, and twenty and a half over against the Plate River: and from thence sailing southwesterly to the Streights of *Magellan* it decreases to seventeen Degrees; and at the West Entrance of those Streights it is but fourteen.

4. That to the eastward of *Brasil*, properly so called, this easterly Variation decreases, so as to be very small at the Islands of *St Helen*, and *Ascension*; and to vanish about eighteen Degrees of Longitude West from the Cape of *Good-Hope*, where the Needle points due North and South.

5. That to the eastward of the foresaid Places, a westward Variation begins; which obtains in the whole *Indian* Ocean; and amounts to eighteen Degrees under the very Equator; about the Meridian of the northern Part of *Madagascar*: and near the same Meridian in thirty nine Degrees of South Latitude it amounts to twenty seven Degrees and a half. From thence easterly the West Variation decreases gradually, so as scarce to exceed eight Degrees at Cape *Comorin*, and not above three upon the Coast of *Java*; but about the *Malucca* Islands there is no Variation at all. The Case is likewise the same, a little to the westward of *Van Dieman*'s Land.

6. That to the eastward of the *Molucca*'s and *Van Dieman*'s Land, in South Latitude, there is

PROPOSITION V.

To find the Declination of the Needle from the North in any Place.

FIND a Meridian Line by the Heavens, as we shew'd by several ways in *Chap.* xx, and by that may

is found another easterly Variation, tho' less than the former both in Extent and Degree: for at the Island of *Rotterdam* it is sensibly less than upon the East Coast of *New Guinea*. And to observe the Proportion wherein it decreases, we may reasonably suspect that it vanishes about twenty Degrees farther to the East, or about two hundred and twenty five Degrees East Longitude from *London*, in twenty Degrees South Latitude; and that there a westerly Variation begins.

7. That the Variations observed at *Baldivia*, and the West Entrance of the Streights of *Magellan*, shew that the East Variation, explained in the third Observation, decreases apace, and cannot reasonably extend many Degrees into the South Sea, from the Coast of *Peru* and *Chili*; leaving room for a small westerly Variation, in that Tract of the unknown World, betwixt *Chili* and *New Zeland*, and betwixt *Hound*'s Island and *Peru*.

8. That in sailing North-West from *St Helen*'s Island by *Ascension*, as far as the Equators, the East Variation continues very small, or as it were constantly the same. So that in this part of the World, the Tract of the Ocean where no Variation appears, is not extended in the Plane of any Meridian, but rather North-West.

9. That in the Entrance of *Hudson*'s Streights, and the Mouth of the Plate River, tho' these are nearly under the same Meridian, yet in the one the Needle varies twenty nine Degrees and a half to the West; and twenty and a half to the East in the other. Whence plainly appears the Impossibility of accounting for these Variations, by the Supposition of two magnetical Poles, and an Axis inclined to the Axis of the Earth: from whence it should follow, that under the same Meridian the Variation should in all Places be the same way.

In order to explain these Phænomena, Dr *Halley* sagaciously supposes the Globe of the Earth to be a great Magnet, having four magnetical Poles; two near the North, and as many near the South Pole of the Earth; and that the Needle is governed by each of these Poles, whilst the Virtue of the nearest

may the Declination of the Needle readily appear; but for Sea-mens Use the following Proposition will show it more readily.

PRO.

nearest Pole predominates over that of the more remote.

But many Particulars being required to determine the Places of these Poles with exactness: the Doctor determines them thus by conjecture. He places the North magnetic Pole nearest to us, in or near the Meridian of the Land's-End of *England*; and not above seven Degrees from the North Pole. By this Pole the Variations in all *Europe*, and *Tartary*, and the North Sea are principally govern'd; tho' it is somewhat affected by that other northern magnetic Pole, situated in a Meridian passing thro' the middle of *California*, and about fifteen Degrees from the North Pole of the World. To this the Needle has chiefly respect in all North *America*, and in the two Oceans, on either side thereof, from the *Azores* westward, up to *Japan*, and beyond.

The two southern magnetical Poles are somewhat farther distant from the South Pole of the World; the one, being about sixteen Degrees from it, is in a Meridian twenty Degrees to the westward of *Magellan*'s Streights, or ninety five Degrees West from *London*. This commands the Needle in all South *America*, in the *Pacific*, and the greatest Part of the *Ethiopic* Ocean.

The fourth Pole seems to have the greatest Virtue, and largest Dominion, being furthest distant from the Pole of the World, *viz.* about twenty Degrees; in a Meridian passing thro' *New Holland*, and the *Celebes*, about one hundred and twenty Degrees from *London*. This Pole predominates in the South of *Africa*, in *Arabia*, and the *Red-Sea*; in *Persia*, *India*, and its Islands, and all over the *Indian* Ocean from the Cape of *Good-Hope* eastwards, to the middle of the great South Sea, that divides *Asia* from *America*.

It remains to be shown how the Conclusions set down are deduced from this Hypothesis. And that the whole may be the better understood; either a Globe or Map should be used, whereon the four magnetical Poles are to be placed in the Situations above described.

And first, it is plain, that our *European* magnetical North Pole being in the Meridian of the Land's-End of *England*, all Places more easterly than that, will have it on the West Side of their Meridian, and consequently the Needle respecting it, with it's northern Point, will have a westerly Variation; which will still increase in sailing eastwards up to some Meridian of *Russia*, where it will be greatest; and from thence decrease again. Thus at *Brest* the Variation is but one Degree

PROPOSITION VI.

To explain the Method which Seamen use for correcting their Sea-Compass; and to find the Declination of the Needle.

KNOWING the Declination of the Needle in the Place where their Compass is made, they remove

gree and three Quarters, at *London* four Degrees and a half; but at *Dantzic* seven Degrees West. Westward of the Meridians of the Land's-End, the Needle ought to have an easterly Variation; but that by approaching the *American* North Pole (which lies on the West Side of the Meridian, and seems to have a greater Force) it is thereby drawn to the westward; so as to balance the Direction given by the *European* Pole, and make a small West Variation in the Meridian of the Land's-End itself. Yet the Doctor supposes, that about the Meridian of the Isle of *Tercera*, our nearest Pole may so far prevail as to give the Needle a small turn to the East, tho' it be but a little Space; the Counter-balance of these two Poles permitting no considerable Variation, in all the eastern Parts of the *Atlantic* Ocean, near upon the West Coasts of *England*, and *Ireland*, *France*, *Spain*, and *Barbary*.

But to the westward of the *Azores*, the Power of the *American* Pole overcoming that of the *European*, the Needle is chiefly affected by that, and turns still more and more towards it, and as you approach it. Whence it happens, that on the Coast of *Virginia*, *New-England*, *New-found-land*, and in *Hudson*'s Streights, the Variation is westward; that it decreases as you go from thence towards *Europe*; and that it is less in *Virginia*, and *New-England*, than in *New-found-land* and *Hudson*'s Streights.

This westerly Variation again decreases as you pass over North *America*; and about the Meridian of the middle of *California* the Needle again points due North; and from thence westward to *Yedzo* and *Japan*, doubtless the Variation is easterly; and half cross the *Pacific* Sea not less than fifteen Degrees. And this is proposed as a Trial of the Hypothesis, that the whole may be examined thereby. And this East Variation is supposed to extend over *Japan*, *Yedzo*, *East Tartary*, and Part of *China*, 'till it meet with the westerly, which is governed by the *European* North Pole.

The Effect is much the same towards the south Pole, only here the South Point of the Needle

move the *Flower-de-Luce* so many Degrees from the North End of the Needle eastward, if the Declination

Needle is attracted. Hence it will follow that the Variation on the Coast of *Brasil*, at the River *Plata*, and so on to the Streights of *Magellan*, should be easterly; if we suppose a Pole situate about twenty Degrees more westerly than the Streights of *Magellan*. And this easterly Variation extends eastward over the greatest Part of the *Ethiopic* Sea, 'till it is counterpoised by the Virtue of the other southern Pole; as it is about the middle betwixt the Cape of *Good-Hope*, and the Isles of *Tristan d' Acunha*.

From thence eastward the *Asiatic* South Pole prevailing, and the South Point of the Needle being attracted thereby, there arises a West Variation very large, both in Quantity and Extent; on account of the great Distance of this magnetical Pole from the Pole of the World. Hence in all the *Indian* Ocean, as far as *New-Holland*, and beyond, there is constantly a West Variation; so that under the Equator itself, it amounts to eighteen Degrees, where it is greatest. About the Meridian of the Island *Celebes*, being likewise that of this Pole, the westerly Variation ceases, and an easterly begins. which reaches according to the Hypothesis, to the middle of the South Sea, between *New-Zeland*, and *Chili*; leaving room for a small West Variation, governed by the *American* South Pole, which, by the sixth and seventh Observations, was shewed to be in the *Pacific* Ocean.

Hitherto the Consideration of the Variation has been simple: whilst no more than two magnetical Poles were regarded at once; but under the Equator, and thro' all the *Torrid Zone*, respect must be had to all four Poles; and their Positions must be well considered; otherwise it will not be easy to determine what the Variations should be: the nearest Pole proving always the strongest; yet not so but that it is sometimes balanced by the united force of two more remote; a notable Instance whereof we have in our eighth Observation; where we find that in sailing from *St Helen*'s, by the Island of *Ascension*, to the Equator, on a North-West Course, the Variation is very little easterly, and in that whole Tract unalterable; because the South *American* Pole (which lies considerably nearest to the foresaid Places) requiring a great easterly Variation, is balanced by the contrary Attraction of the North *American* and *Asiatic* Pole; each whereof singly, is in these Parts weaker than the *American* South Pole: and upon the North-West Course the Distance from this latter is very little varied, And as you recede from the *Asiatic* Pole, the Balance is still preserved by the Access towards the North

clination be to the West, and contrariwise if to the East.

YET

North *American* Pole. And little or no regard need here be had to the *European* North Pole; it's Meridian being a little removed from the Meridians of these Places; and of itself requiring the same Variations that we here find. And after the same manner we might reason upon the other Variations thro' the *Torrid Zone*.

And thus by a simple Hypothesis Dr *Halley* has, with great Ingenuity and Probability solved the Phænomena of the Variation; tho' there still remains a great Difficulty or two to be considered. For it is new and strange to attribute more than two Poles to a Magnet; whereas this Hypothesis attributes four to the Earth. And again, the Variation is found different at different Times in the same Place; which can by no means proceed upon the Supposition of a fixed unvaried Situation of the magnetical Poles. The Doctor therefore deterred by these Considerations gave over his Thoughts upon the Subject for several Years, but at length renewed them; and with an adventurous indeed, but probable Hypothesis, happilly solved the Difficulties. For, by comparing together the Observations made upon the Variation of the Variation he shewed first, that whatever these Differences arise from it must move from East to West. 2. That this motion is not desultory, but gardual and continued; because the Declination of the Needle changes gradually and regularly. 3. That it must needs be something great whose Force can produce one and the same concurrent Effect in such very distant Regions of the Earth. 4. That as we know of no Fluids that have the least magnetical Virtue, it is not probable that this Variation should proceed from the Motion of any Fluid lodged in the Cavities of the Earth. 5. That whatever Body it was. it could only move circularly round the Center of the Earth, without changing the Center of Gravity of the Terraqueous Globe,. and thus occasioning great Changes on it's Surface; such as strange Refluxes of the Sea, and Inundations of Land, of which there appears no Signs in History. From all which it follows, that a certain large solid Body, contained within, and every way separated from the Earth (as having it's own proper Motion) and being included, like a Kernel in it's Shell, revolves circularly from East to West, as the exterior Earth revolves the contrary way in the diurnal Motion. Whence it is easy to explain the Supposition of the four magnetical Poles above attributed to the Earth, by allowing two to the nucleus, and two to the exterior Earth. And as the two former perpetually alter their Situation by their circular

YET becauſe the Declination varies according to the Place they come to, the Chart muſt be made ſo as the *Flower* may turn leſs or more from the North End of the Needle, which muſt be done according as they find the Declination to be.

TO find which moſt Seamen do thus: They find in what Point the Sun riſes, or ſets, and tho' in the time between both, they have gone ſome way, yet the Declination will not alter much in ſo ſmall a Diſtance.

IF the Eaſt and Weſt Line, or any Point found, be the ſame with that, the Compaſs ſhows there is no Variation; but if it be a Point farther from, or nearer to, the North than that which the Compaſs ſhows, then there is ſome Variation to the Weſt, or Eaſt The Quantity of the Declination is thus known: Take the Differences between the North

circular Motion, their Virtue compared with the exterior Poles, muſt be different at different Tines; and conſequently the Variation of the Needle will perpetually change.

The Doctor attributes to the Nucleus an *European* North Pole, and an *American* South one; on account of the Variation of the Variations obſerved near theſe Places, as being much greater than thoſe found near the two other Poles. And he conjectures that theſe Poles will finiſh their Revolution in about ſeven hundred Years; and after that time the ſame Situation the Poles obtain again as at preſent; and conſequently that the Variations will be the ſame again over all the Globe. So that it requires ſeveral Ages before this Theory can be thoroughly adjuſted.

He aſſigns this probable Cauſe of the circular Revolution of the Nucleus; that the diurnal Motion being impreſſed from without, was not ſo exactly communicated to the internal Parts, as to give them the ſame preciſe Velocity of Rotation as the external: Whence the Nucleus being left behind by the exterior Earth, ſeems to move ſlowly in a contrary Direction; or from Eaſt to Weſt, with regard to the external Earth, conſidered as at Reſt in reſpect of the other.

And to remove the Prejudice that may ariſe againſt this Hypotheſis, on account of it's Novelty and ſtrangeneſs, and to anſwer the Objections that may be made to it; the Doctor argues and defends the whole with great Sagacity and Probability.

Point

Point by the Compaſs, and the Eaſt and Weſt by the Sun, and ſubſtract the leſſer from the greater half the Remainder is the Declination ſought; and ſo far the *Flower-de-Luce* is to be removed from the North end of the Needle.

THIS Method hath two Diſadvantages; 1. The Sun ſeems to riſe when it is thirty four Minutes under the Horizon; which will cauſe ſome Error in the Declination: and tho' near the Equator 'tis but ſmall, yet in Places remote it will ariſe to two Degrees. 2. The Sun is often covered with Clouds when riſing, and always almoſt in the *Torrid Zone.*

THEREFORE Seamen ſometimes uſe another Method, that is not ſo liable to Error. They obſerve the Point the Sun is in by the Compaſs any time after it's riſing, and then take the Altitude of the Sun; and in the afternoon they obſerve when the Sun comes to the ſame Altitude, and obſerve the Point the Sun is then in by the Compaſs, for the middle between theſe two is the true North or South point of the Compaſs; and the difference between that and the North or South upon the Card which is pointed out by the Needle, is the Variation of the Compaſs, and ſhews how much the North and South given by the Compaſs, deviates from the true North and South points of the Horizon.

EXAMPLE.

SUPPOSE in the forenoon Obſervation, when I take the Sun's Altitude, I find the Sun, by my Azimuth Compaſs, to bear South-Eaſt; then waiting till the Sun in the afternoon declines to the ſame Altitude, as in the forenoon Obſervation, I find by the Azimuth Compaſs that he bears Weſt-South-Weſt, the middle Point between South-

East and West-South-West, if reckoned to the ſouthward, is South by Weſt, or if to the northward, it is North by Eaſt, which proves that the South by Weſt point of the Compaſs, is the true South, and the North by Eaſt Point, is the true North, and as the *Flower-de-Luce*, or North point of the Compaſs, lies one point to the weſtward of the North by Eaſt point of the Compaſs, which points to the true North, it proves that the Variation is one Point weſterly, or that the *Flower-de-Luce* lies one point to the weſtward of the true North, *&c.*

THEY ſometimes uſe a fourth Method. They that are ſkilled in ſpherical Trigonometry, or can uſe an univerſal Planiſphere, by taking only one Obſervation of the Sun's Altitude, by which, with the Latitude of the Place, and the Sun's Declination, thoſe that underſtand ſpherical Trigonometry may find the Sun's true Azimuth, or point of the Compaſs that he bears upon, in the Heavens, which compared with the point that the Sun bears upon by the Compaſs, their difference is the Variation; as for Inſtance, if the Sun's Azimuth found by Calculation be 45 Degrees, or 4 Points, from the North weſterly, which to ſpeak in the Terms of Navigation is North-Weſt, but if by the Compaſs, the Sun bears at the ſame time North-Weſt by North, that Point difference is the Variation of the Compaſs, and ſhews that the North Point of the Compaſs declines one Point to the weſtward, or that the Variation is one Point weſterly; and then will every Point of the Compaſs be removed, one Point towards the left Hand, as the Weſt Point of the Compaſs will ſtand Weſt by South, the South Point will direct to the true South by Eaſt, *&c.*

THIS being a thing ſo uſeful at Sea, and a great many having Tables of Logarithms, Sines,

and Tangents that do not throughly understand spherical Trigonometry; it may not be amiss, for the sake of such, to insert the following Operation to find the Sun's Azimuth, for which the most convenient *Data*, as being both the most easily found, and the least trouble in the Operation, is,

THE Sun's Altitude, his Declination, and the Hour of the Day given to find his Azimuth.

Note. The Sun's Altitude is found by a Quadrant, his Declination by the Tables for that purpose, in most Books of Navigation, and the Hour of the Day by a good Watch; and then,

As Sine Complement of Sun's Altitude, to Sine of the Hour from Noon, So Sine Complement of Declination to Sine of the Sun's Azimuth, from the South or North.

EXAMPLE.

LET the Sun's Altitude be 47 48 (it's Complement is 42 12) the Hour from 12, is 2 Hours 9 Minutes which is either 9 Minutes after 2, or 9 before 10, which, at 15 Degrees to an Hour, is 32 15, the Declination 20 12 North, it's Complement 69 48 then *Co. Ar.*

As Sine Comp. of Altitude —	42.12.0.17281
To Sine of the Hour from Noon	32.15.9.72723
So Sine Comp. Declination —	69.48.9.97243
To Sine of the Azimuth —	48.12.9.87247

WHICH 48 12 is the Sun's Azimuth from the South, or taken from 180 Degrees, leaves 131.48 the Azimuth from the North.

ANOTHER way to find the Azimuth, is by having the Latitude of the Place, the Decli-

nation of the Sun, and the Sun's Altitude given, and then the Method of finding it is,

ADD the Complement of Altitude (or Zenith Distance), the Complement of Latitude of the Place, and the Complement of the Sun's Declination together, and from their half Sum substract the Complement of Declination.

THEN to the Complement Arithmetical of the Sines of the Complement of Latitude, and of the Complement of Altitude, add the Logarithm Sines of the half Sum, and remainder half, the Total of these four Logarithms, is the Sine-Complement of half the Azimuth.

Note. If the Sun's Declination be South, and the Latitude North; or the Declination North, and Latitude South, you must, instead of the Complement of Declination, use the Declination added to 90, for what is there meant by the Complement of the Sun's Declination, is always it's Distance from the elevated Pole.

EXAMPLE.

	D.	M.	
Sun's Altitude —	8	10	To find the Azimuth.
Declination South -	20	13	
Latitude North —	51	32	

	D.	M.
Complement of Altitude — — —	81	50
Complement of Latitude — — —	38	28
Declination added to 90 Degrees —	110	13
Sum ——	230	31
Half Sum ——	115	15
Complement of Declination ——	110	13
Remainder ——	5	2

OPE-

OPERATION.

Comp. Altitude —	81	50	*Co. Ar.*	0.00442
Comp. Latitude —	38	28	———	0.20616
Sine of the ½ Sum -	115	15	———	9.95638
Sine of Remainder —	5	2	———	8.94317
		Sum	———	19.11013
		Half Sum	———	9.55506

THAT half Sum is the Sine-Complement of 68 57, which doubled is 137 54, the Azimuth from the North required.

CHAP. XXXIX.

Of the Line of a Ship's way.

THIS is the moſt difficult Part in all Geography, of which Authors have written ſo obſcurely, and a great many ſo falſely, that the Readers can only have from them an obſcure Idea without underſtanding them. We ſhall endeavour to give an Explication as clear and diſtinct as poſſible: and the Reader muſt give cloſe Attention to it, and to make this Explanation the more compleat, and render thoſe Directions intelligible and applicable, which have been left ſo obſcure and impracticable, we ſhall, in this Edition, exhibit thoſe Methods, by which not only a general Idea of Navigation may be formed, but by which alſo all the uſeful practical parts thereof are actually performed, and that with reſpect to Courſe, Diſtance, Latitude, Longitude, and all the *Data* and *Quæſita* that can occur in the Practice of Navigation, in order to which (omitting plain Sailing, which is but the A B C of Navigation, and falſely ſuppoſes the Surface of the terraqueous Globe to be a regular Plain) we ſhall act from another Foundation, and deduce all our ſubſequent Rules and Tables from that Suppoſition, or rather reality of the Earth's being a Globe; and not only adapt our Tables to that Principle, but give the Reaſons and Conſtructions of them, in

in order to the better underſtanding of which the following Propoſitions are previouſly neceſſary.

PROPOSITION I.

If two places are ſituated in one Meridian, or lie North or South from it, all the places between them will be ſituated the ſame way from them.

THE Propoſition is manifeſt, if rightly conceived. By the Places between two Points we underſtand all the Places in that Arc of a great Circle, which paſſes thro' the two Places. Call the firſt Place from which the other lies, the firſt Place; and the Place of the other the ſecond Place; and the firſt Place is to be conceived, as if it lay in the middle of the other Places about it, and under the braſs Meridian in the Globe, and an infinite Number of vertical Circles drawn from it to the Horizon, thro' the other Places, and ſo the Angle made, with the Meridian of the firſt, is the Angle wanted; for that Angle denotes the Situation of the ſecond Place from the firſt. If then we conceive all the Points between two Places of the ſame Meridian, 'tis plain all their Meridians will be the ſame with the vertical drawn thro' all their Places; and therefore all the Places between them lie the ſame way from the firſt, either North or South.

PROPOSITION II.

If two places be taken in the Equator, of which the Situation of the one to the other is wanted, the ſecond will lie from the firſt Eaſt or Weſt; and the ſecond will lie the ſame way from all the points between them.

FOR the underſtanding whereof, take a Point on the Equator, and let the wooden Horizon repreſent it's Horizon, or the Poles of the Globe be brought to the Horizon; then take another Place on the Equator, whoſe Situation from the firſt is wanted, 'tis plain it will lie either Eaſt or Weſt; for the Equator is then a vertical Circle which cuts the Meridian at right Angles. The ſame is true as to all the intermediate Points, which if brought to the braſs Meridian, the wooden Horizon will be their Horizon, and the Equator a Prime vertical to them which cuts the Meridian at right Angles; and therefore the ſecond will lie the ſame way from all the intermediate Points either eaſtward or weſtward.

PROPOSITION III.

If the ſecond Place be not ſituated in one and the ſame Meridian with the firſt, or both not in the Equator; the ſecond Place will not be ſituated from the intermediate Point, on the ſame Point of the Compaſs but in different Points in different Places.

ON this depends the Knowledge of the Line which a Ship deſcribes; and therefore Readers ſhould underſtand it well.

TAKE two ſuch Places on the Globe, as *Amſterdam* from which, and *Pernambucca* in *Braſil*, to which the Voyage is to be made, bring *Amſterdam* to the Meridian, and elevate the Globe for it's Latitude, and fix the Quadrant of Altitude at the Zenith; and turning it about to *Pernambucca* it will ſhow, on the Horizon, the Point on which it lies from *Amſterdam*; and the Arc between them contains the intermediate Points. 'Tis to be ſhown that *Pernambucca* does not lie the ſame way from each of theſe Points.

AND here 'tis to be remembred, that the Angle made by the Meridian of the firſt Place, and the Vertical of the other paſſing through, gives the Point that the ſecond lies on, which is meaſured on the Horizon.

TO ſolve the Propoſition; take any two Points between two Places, 'tis better to take ſuch two as have Circles of Longitude drawn thro' them on the Globe, and becauſe the Quadrant paſſes thro' all theſe Places and *Pernambucca*, it will denote the Vertical in which *Pernambucca* lies from them. And thus the Angles, which that Vertical makes with the Meridian of each Place is the Angle of Poſition, and ſhows the Points that *Pernambucca* lies in from each intermediate Point; but theſe Angles are not all of the ſame Degrees, as appears to the Sight. Or more plainly, if you meaſure them with the Compaſs, or by the help of a Curve that can be adapted to the Globe; or if the Places be brought to the Zenith, and the Pole elevated for their Latitudes, and the Quadrant applied to each, you will have the Angle in Degrees on the Horizon.

COROLLARY.

THE rectilineal Maps, or Sea-Charts, are then very faulty, for there one Place ſeems to be on the ſame Point from another with all the intermediate Places, becauſe their Meridians are parallel, tho' they meet at the Pole; but Seamen do not regard that, if they can firſt ſee the Point that the Places they ſail to lies in, from the Places they come from.

PROPOSITION IV.

If a Ship be to ſail from one place to another, that does not lie in the ſame Meridian, or both in the Equator, ſo as to keep the vertical Circle between the two places, the Ship will then every Minute change the point ſhe ſailed on.

THIS is plain from the preceding Propoſition: for ſuppoſing the Voyage from *Amſterdam* to *Pernambucca* is to be the ſhorteſt that can be drawn on the Globe; then becauſe the Ship is always in the Voyage directed to *Pernambucca*, and as before there are ſtill different Points in the different Meridians; 'tis plain the Ship muſt ſteer her Courſe on different Points, to come to *Pernambucca*: but it will be otherwiſe if the two Places were both in one Meridian, or on the Equator.

PROPOSITION V.

A Ship cannot always ſail on different points, but muſt for ſome time at leaſt ſail on the ſame point. Therefore ſuch Way, or Line, is to be ſailed in, that the two neareſt points may be on the ſame point, tho' that be not the ſhorteſt Courſe.

FOR all Motion is performed in ſome Time; nor can a Ship change it's Point every Moment, but muſt for ſome Time ſail one way; nor could Seamen know the Points to ſteer on, if they were to change them ſo often. Therefore that muſt be the moſt commodious ſailing, in which the two neareſt Points are directed the ſame way; ſo as the Ship may be directed ſtill to the Point, and at laſt come to the deſigned Port. This then being ſuppoſed, we are to enquire what Way is beſt for a Ship

a Ship to move in: and if the two Places are in one Meridian it will be a Part of the Meridian; if in the Equator, a Part of the Equator; if in a parallel Circle, it will be a Part of it; but if in any other Circle, it will be in another Line, and not in the Circle, as we ſhall ſhow.

PROPOSITION VI.

If a Ship ſail always due North or South, that is, if the places, to which and from which, be in the ſame Meridian, the Ship's Way will be a portion of the Meridian.

THIS is proved from the firſt Propoſition of this Chapter; for the Place ſailed to is ſituated the ſame way from all the intermediate Points, as was there ſaid; but by the preceding Propoſition, ſuch a Way is to be choſen, as is moſt commodious, whoſe two neareſt Points are ſituated the ſame way; and ſeeing an Arc of the Meridian is ſuch a Way, this will be the Way the Ship moves in, while it goes ſtill North or South.

PROPOSITION VII.

If a Ship ſail Eaſt or Weſt on the Equator, the Ship's Way will be a portion of the Equator.

WE ſhowed, in the ſecond Propoſition, that if two Places on the Equator, to which, and from which, a Ship moves, be choſen, the firſt Point will lie the ſame Way from all the intermediate Points. And becauſe the Ship is continually directed that way, an Arc of the Equator will be the Ship's Way; and becauſe in the fifth Propoſition we ſuppoſed, that ſuch a Way is to be choſen for the Ship's Way as is moſt commodious, whoſe

whose two adjacent Points lie the same way, a Portion of the Equator will be such a Way, and therefore to be chosen for the Ship's Way.

PROPOSITION VIII.

If a Ship, not in the Equator, move East or West, it will describe not a Part of a great Circle, but a Part of the Parallel in which it is.

BECAUSE the Ship going from one Meridian to another is supposed to be directed to the same Point, it will not move in a vertical Circle, but go to another Point in the same Parallel in another Meridian; for the Points of that Parallel are such, that if Tangents be drawn to them, they will run East and West, with respect to the same Points; and because the Ship is supposed to be still directed that way, it will always touch the Parallel in some Point; or because each two nearest Points in that Parallel, are such, that one is situated to the same East or West Point: nor is there any other Line on the Globe whose Points are such: and therefore the Ship's Way is the Parallel in which it is.

PROPOSITION IX.

If a Ship sail in the same Parallel, the Ship's Way will be a Part of the Parallel, tho' that be not the shortest Way.

FOR that Line is chosen for the Ship's Way in which the Ship can come to the designed Port; being directed still to the same Point; or whose two nearest Points lie the same Way: but the Points in a Parallel Circle are such; therefore a Part of it will be the Ship's Way.

COROL-

COROLLARY.

THERE is therefore a three-fold Situation of Places, from one of which, when we sail to the other, the Ship's Way is the Periphery of a Circle; 1. If both Places are in one Meridian. 2. If both be in the Equator; or, 3. both in the small Parallel. In the two former the Ship's Way is the same with the shortest Distance between them; but in the third Situation the Ship's Way is not the shortest Way; for that is the Arc of a great Circle between the two Points. In any other Situation of Places the Ship's Way cannot be Part of a Circle; as we shall show in the following Proposition.

PROPOSITION X.

If a Ship sail, in any Part of the Ocean, to a Point that is not a Cardinal one, and keep still to the same Point, the Ship's Way is not a Part of a Circle, or any Curve returning to itself, but a curve Line, like a spiral, turning infinitely round the Earth, and inclining continually towards the Pole but never centering in it.

LET us suppose a Ship to set sail from any Place; after 'tis come to a Point in the next Meridian, 'tis directed to that Point of the next Meridian which is situated on the same Point from the other Place left; and so in going into the other Meridians; but all these Points of those Meridians do not make a Circle, but a Curve like a Spiral. This will be better understood by seeing it on the Globe than by many Words.

DEFI-

DEFINITION.

LOXODROMY is a Ship's Way, sailing still to any one Point that is not one of the Cardinals.

THIS is the meaning of the Word, but the Definition of the Thing itself, according to it's Nature and Properties, is not easy to be understood; it being neither a spiral Line, as some think, nor depending on any Property of the Loadstone, as others imagine, because the Ship follows the Direction of the Needle; nor composed of the small Parts of many Circles, as *Nonnius* says, because the Parallels are made the same way by the Motion of the Ship, as the *Loxodromics*; nor is *Snellius*'s Explication of it plain, who says, That the *Loxodromic* is a Line on the Superficies of the terrestrial Globe, which Surface, a right Line touching every where, makes equal Angles with all the Meridians drawn thro' these Points of Contact; for *Snellius* doth not explain how such a Tangent is to be conceived or drawn; and, properly speaking, a *Loxodromic* hath not right Lines touching it, being a solid Line; whereas Tangents are only drawn to curve plain Lines; and infinite Tangents may be drawn to each Point in solid Lines: and besides, this Definition agrees to other Draughts of Lines when such a Tangent, to any Point of a meridian and curve Line drawn from the next Meridian, may be conceived.

OUR Definition is proposed thus: *A* Loxodromic *Line is a curve Line surrounding the Earth by several Windings, of which any point lies the same way from all the rest in it; or in which if two points be taken, the one lies from the other, and all the intermediate points, the same Way; or from each point of which, if circular Lines be drawn to all the rest of the*

the points, these Arches will make the same Angles with the Meridians that pass thro' each point. This Definition is essential, and is the true Description of the Rumb-Lines upon the Globe.

PROPOSITION XI.

If a Ship sail not on a Meridian, nor in the Equator, nor in a parallel Circle, and be directed still in that point in which the designed Port lies, from the Port left, the Ship will never come to the designed Port, but be removed more and more from it.

THIS famous Property in sailing was at first a Wonder to Sailors, when first observed in the last Age, or the Time of *Peter Nonnius* a Mathetician of *Portugal*; for a certain skillful Pilot, who sailing some time still eastward to a Port that lay due East from him, found that thereby he never came to it, desired that *Nonnius* would give him the Reason of so strange a thing, which gave the first rise to this Enquiry. And *Nonnius* a little after published two Books about it; and afterward several Mathematicians were at work about this curve Line; at last Sailors found there was a necessity of having regard to it, and Tables were made for it, of which afterwards.

PROPOSITION XII.

1. *When a Ship is to sail in the same Meridian, or North and South, she must be directed if possible still one Way; that is, the Meridian must be the Ship's Way.*

2. WHEN a Ship is to sail from one Place in the Equator to another in it, that is either East

or Weſt, the Ship muſt be directed that Way, or the Equator muſt be the Ship's Way.

3. WHEN a Ship is to ſail from one Place in a parallel Circle, to another in it, ſhe muſt not be directed to the Point in which the one Place lies from the other, elſe ſhe would never come to it, but wind about the Earth, as it were, in a ſpiral Line, towards the Poles, but the Pilot is to ſteer due Eaſt and Weſt; for thus ſhe deſcribes a Parallel to the Equator, and ſo will come to her Port.

4. WHEN a Ship is to ſail from one Place to another, which are neither in one Meridian, nor in the Equator, nor in a parallel Circle, the Ship is not to be directed to that Point in which the firſt Place lies from the ſecond, for thus the Ship would deſcribe a *Loxodromic* Curve, which will not paſs thro' the other Place; but the Direction muſt be in that Line, which when the Ship goes, ſhe will deſcribe a *Loxodromic*, that will paſs thro' the other Place, or into that Line which makes an Angle, with the Meridian, equal to the Inclination of the *Loxodromic* which paſſes thro' theſe two Places. Theſe all follow from the preceding Propoſition.

PROPOSITION XIII.

An infinite Number of Loxodromics *may be conceived to come from any place of the Earth, and alſo infinite Verticals; but there are only counted twenty eight round about a place*, viz. *ſeven in the Quadrant between the Meridian and Parallel of the place; and ſo they divide the Angle into eight equal Parts, and each two neareſt are diſtant equally; but the Parallel is called the eighth* Loxodromic

THEY are called by the ſame Names that the Winds or Points are. They that are ſeen on the Globes

Globes come from the Center of the Sea-Compass on it, and also from other Points of the Meridian and to turn round the Earth.

AND for Practice at Sea; the intermediate *Loxodromics* are denominated by their Distance from the next *Loxodromic. For Example*; One third, or one fourth, more northerly or easterly, *&c.*

PROPOSITION XIV.

The Loxodromic *between any two Places is (as to Sense) equal to the Hypothenuse of a plain right-angled Triangle, one Leg being equal to the Difference of the Latitude of those two Places, the other equal to the Difference of their Longitude taken on a Parallel, which is in the middle between the Parallels of the two places.*

SUCH Triangles are called *Loxodromics*; but for accurate Calculation, places must be taken very near one another, even within a Minute.

COROLLARY.

WE may hence calculate the *Loxodromic* Line from one place to another; and that with the help of the following Proposition.

PROPOSITION XV.

The Parts of one Loxodromic *intercepted between Parallels equi-distant are equal.*

THEREFORE a great many small *Loxodromic* Triangles may be conceived in each *Loxodromic*; of which if the *Loxodromic* of one be calculated, the Quantity of the *Loxodromic* from one Place

Place to another, whose Latitude is known, is known also.

PROPOSITION XVI.

Having the Difference of the Latitude and Longitude of two places, to find the Loxodromic *in which a Ship must sail from one place to the other; or having on the Globe two places, to find which way a Ship must steer in going from one to the other.*

THIS is the chief Problem in Navigation, to which the rest are subservient. If there be no Difference of Latitude, the Ship's Way will not be a *Loxodromic*, but a Parallel of these Places; tho' 'tis commonly called the eighth *Loxodromic*, because 'tis formed the same way as the rest, by the Motion of the Ship, which is directed East or West. If therefore their Latitude be the same, they say the eighth *Loxodromic* should be taken, and the Ship steered still due East or West, tho' not strait to the designed Port, yet by that false Direction the Ship will come to it.

IF there be no Difference of Longitude, there will be no *Loxodromic*, but a Part of the Meridian of both Places; and the Ship is to be directed North or South.

BUT if the Places differ both in Latitude and Longitude, and you would work by the Globe, let the given Latitudes be marked on the brass Meridian, and if the Parallel of one Latitude have on it the Center of a Sea-Compass, from which *Loxodromics* are drawn, bring that Center to the Meridian, under the marked Latitude; then turn the Globe 'till as many Degrees on the Equator pass thro' the Meridian, as are in the Difference of Longitude; then observe in what *Loxodromic* the Point is which is under the other marked Point of

of the Meridian, and that will be the one sought, which will show to what Point the Ship is to be directed, to come to the designed Place. If there be not a Point of a *Loxodromic* under the Mark, the middle must be taken between the two next *Loxodromics.*

BUT if there be not the Center of a Compass in any of the two Parallels, chuse a *Loxodromic* that seems near that which is wanted, which bring to one Point mark'd on the Meridian, and turn the Globe, as before, 'till the Difference of Longitude pass thro' the Meridian; and if a Point of the assumed *Loxodromic* be under the other Point marked in the Meridian, you have it at once; if not, assume another Meridian, and try, as before, 'till you find a Point in the *Loxodromic* under the Mark, or near it; and call it by the nearest *Loxodromic*, or by how much 'tis beyond, or comes short of it.

IN the Sea-Charts it is as the Point the one lies in from another, tho' in those of equal Degrees of Latitude 'tis false; but of unequal 'tis accurate enough.

SAILORS have also another Method, easy enough, by the Solution of right-angled plain Triangles; but for this they use a Table of meridional Parts; of which we treated in *Chap.* xxxii, and now proceed to give the Original and Construction thereof, with it's application to the finding the *Line* of *a Ship's way*, according to our promise in the Title of this Chapter.

IN order the better to understand the Nature of the Table of meridional Parts, we are to consider, that this Earth, upon which we live, as composed of Land and Sea, is a Globe, or of a globular Form, and moves upon it's own Axis, which is terminated by two Poles, or opposite Points of the Surface of the Earth, between which,

and equally diſtant from each, is the Equator which paſſes round the Earth, and divides it equally into the northern and ſouthern Hemiſpheres; and any other Circles drawn round the Globe, or imagined to be drawn round the Earth it ſelf, parallel and equidiſtant from the Equator, either on the North or South of it, are called Parallels of Latitude, North or South, according to their Situation from the Equinoctial; alſo any Lines drawn along the Surface of the Globe, at the neareſt diſtance from Pole to Pole, (or imagined to be drawn ſo upon the Surface of the Earth) are called Meridians, which therefore at whatſoever Diſtance they may be from one another in the Equinoctial, yet as they all meet, and concur in the Poles, they incline nearer to each other as they approach it; and as every two Meridians contain the ſame number of Degrees of Longitude, as they come nearer the Poles, which were contained between them in the Equator, when further aſunder, it will follow that a leſſer Space, or fewer Miles, make a Degree of Longitude nearer the Poles, than are contained in a Degree of Longitude, in the Equator; and as a Degree of Longitude in the Equator, is always equal to a Degree of Latitude, upon any part of the Globe; it will neceſſarily follow, a Degree of Longitude bears continually a leſs proportion to a Degree of Latitude, as they approach nearer either Pole.

BUT as former Authors have not found any way to transfer thoſe curving inclining Meridians from the Globe to a Plain, it being impoſſible for a true plain to co-incide with the Surface of a Globe, or (Mathematically ſpeaking) ſo much as to touch it any where, but in a Point, as a right Line can touch a Circle, they concluded Globular Sailing impracticable, and for many Years contented themſelves with Plain-Sailing, which, with-

out

out any regard to the Convexity of the Earth, upposeth it to be a plain Superficies only.

BUT our ingenious Countryman Mr *Edward Wright*, very sensible of the Errors which must unavoidably be the consequence of trusting our Navigation upon a Supposition so evidently false, substituted another Projection instead of the plain Chart, which is now (though wrongfully) known by the name of *Mercator*'s Chart. In this, although the Degrees of Latitude are not every where equal, as they are upon the Globe, and consequently the same extent of the Compasses will not contain just the same Number of Miles in every part of the Chart; yet it is so contrived, that the Degrees of Longitude bear the same proportion to the Degrees of Latitude in any Parallel, that they do in the same Parallel upon the Globe, which is an Excellency, that the plain Chart is entirely a Stranger to.

IN this Chart the Degrees of Longitude are every where equal, and therefore to keep the Meridians parallel, and retain the same proportion between the Degrees of Longitude, and the Degrees of Latitude that there is upon the Globe, the Degrees of Latitude upon the Meridian are protracted, or lengthened; so that whereas upon the Globe, the Degrees of Latitude are every where equal, *viz.* 60 Miles to a Degree, and in Latitude 60 Degrees, one Degree of Longitude, is but half as much as a Degree of Latitude, *viz.* 30 Miles; so in *Mercator*'s Projection, a Degree of Longitude is the same in Latitude 60, as it is under the Equinoctial, and a Degree of Latitude is twice as long; and in like manner, the same proportion is held between the Degrees of Latitude and Longitude, upon *Mercator*'s Chart every where as is upon the Globe.

BUT although the Degrees of Longitude and Latitude, did by this means retain their true pro-

portion between themſelves, yet as the Degrees of Longitude are every where the ſame, it will follow, that the Meridians, and conſequently the Diſtances, are every where (except under the Equinoctial) diſtorted, and the more ſo as they come nearer the Pole, inſomuch that the ſame extent of the Compaſs, which contains 60 Miles under the Equinoctial, contains but 20 Miles, or leſs, between Latitude 70 and 71, and nearer the Poles.

BUT as it was pity ſuch an excellent Invention ſhould be loſt, for want of a way to meaſure Diſtances upon it, we have likewiſe ſubjoined the Method of making a Scale, whereby at one Extent to meaſure a Diſtance upon *Mercator*'s Chart: The Scale is formed from the ſame mathematical Principles with the Chart itſelf; we ſhall firſt give the Conſtruction of one, and then of the other.

WE have obſerved above, that by reaſon of the Difficulty of truly drawing upon a plain, any conſiderable part of the Surface of the Globe, with inclining Meridians, and all the other properties of the Globes, they endeavoured to find out a right lined Projection, which might be equally true, and yet eaſier in Practice, in order to which it is premiſed as a Foundation,

1. THAT the Peripheries, or Circumferences, of all Circles, are in a direct proportion to their Diameters; and conſequently to their Semidiameters or Radiuſes. And,

2. As the Periphery of one Circle, to the Periphery of another, of a different Magnitude, So a Half or a Quarter, or any other part of the firſt Circle's Periphery, to the like part of the other Circle's Periphery.

3. The Semidiameter or Radius of any Parallel of Latitude, is the Sine Complement of that Latitude; theſe conſidered it will be then,

1. AS

1. AS Radius: To Sine Complement of any given Latitude, So 60, the Miles in a Degree of Longitude in the Equator, to the number of Miles contained in a Degree of Longitude, in the Latitude proposed.

2. BUT it is also demonstrable, that As Sine Complement of any Arch to Radius, So is Radius to the Secant of the same Arch.

IN the Scheme let C be the Center of the Earth, and A B D be a Quarter of a Meridian, let A be the Pole, and C D the Semidiameter, or Radius of the Equinoctial, draw the Tangent D E, and the Secant C B E, draw also the perpendicular B G (the right Sine of the Arch D B) and F B equal to C G, the Sine Complement of the same Arch, then is B D the Latitude or Distance of B from the Equinoctial: A B the Complement of Latitude: B G is the Sine of the Latitude, and C G equal to F B the Sine Complement of Latitude. C B equal to C D is Radius, D E the Tangent, and C E the Secant of the Latitude.

HENCE, for the first, it will be, As C D, (*Plate* XI. *Fig.* B.) the Radius or Semidiameter of the Equinoctial, To C G equal to F B, So one Degree, or any other part of the Equinoctial to one Degree, or the like part of the Parallel passing through B, that is as Radius to the Sine Complement of Latitude, So 60, the Miles in a Degree of the Equinoctial, to the Miles in one Degree of Longitude, in the Parallel of B.

Secondly, As C G (equal to F B) Sine Complement of Latitude, to C B (equal to C D) Radius, So C D Radius to C E the Secant of Latitude *Euclid*, *Lib*. vi. *Prop*. iv.

THIS being granted, it may thus be applied to a Demonstration of the truth of the Construction of *Mercator*'s, or, more justly, Mr *Wright*'s Chart.

IN this Projection the Meridians are proposed parallel to each other, and consequently the Diameter of any or every Parallel, is likewise supposed equal to that of the Equator, and hence the Radius of any Parallel is equal to the Radius of the Equator; and therefore, in the last mentioned Scheme, FB or CG will be every where equal to CD, but when CG is become equal to CD, it is evident CB will become equal to CE, and consequently the Radius of the Meridian, at any Parallel, will be equal to the Secant of the Latitude of that Parallel, also as a Degree, or any small Arch upon the Equator, is equal to a Degree, or the like Arch upon the Meridian, upon the Globe, it will be as the Secant of any Parallel is to Radius, so is the length of a Degree, or any small Arch upon the Meridian, to the Length of a Degree, or the like Arch upon that Parallel, and therefore a Degree on any Parallel, will be increased in the same Proportion, as the Secant of Latitude is greater than Radius; as for Instance, the Secant of 60 is just twice Radius, therefore a Degree of Longitude which should be but half as much as a Degree of Longitude in the Equinoctial, is there, and all over the Projection, equal to a Degree in the Equinoctial, and therefore in Latitude 60 just twice as large as it should be, and the Degrees of Latitude which are every where equal upon the Globe, are double in Latitude 60, to what they are in the Equinoctial, by which means the proportion in northing and southing, is the same to that of the easting and westing upon this Projecton, as it is upon the Globe, and the Length of a Degree, or any small Arch upon the enlarged Meridian, must every where be to a Degree, or like Arch of the Meridian on the Globe, as the Secant of the Latitude is to Radius.

HENCE

HENCE supposing any small Arch of the Meridian to be Radius, the following Corollaries may be deduced.

1. THAT the Length of a Degree, or any small Arch upon the enlarged Meridian, is every where equal to the Secant of the Arch contained between it and the Equator.

2. THE distance of any Point in the enlarged Meridian from the Equator, is equal to the Sum of all the Secants contained between it and the Equator.

3. THE Distance between any two Parallels, on the enlarged Meridian (being both on the same Side of the Equator) is equal to the Difference of the Sums of all the Secants of every Minute, contained between each Parallel and the Equator.

4. THE Distance between any two Parallels upon the enlarged Meridian (being on contrary sides of the Equator) is equal to the Sum of the Sums of all the Secants contained between each Parallel and the Equator.

UPON the Principle of this second Corollary it is that the Table of meridional Parts is formed; *viz. That the Distance of any Point, upon the enlarged Meridian, from the Equator, is equal to the Sum of all the Secants contained between it and the Equator.* It is plain that if to 00000 (which if the expression be proper, may be said to be the meridional Parts of 00 *deg.* 00 *min.*) we add the natural Secant of 00 *deg.* 0 *min. viz.* 10000, the Sum will be 10000 the meridional Parts for 0 *deg.* 1 *min.* to which if we add the natural Secant of 0 *deg.* 2 *min.* which is again 10000 (because the Secants of such small Arches, where they fall upon the tangent Line, at so near a right Angle, increase insensibly) the Sum is 20000, the meridional Parts for 2 *deg.* 00 *min.* &c. But this will appear more conspicuous towards the latter part of the Table,

where the natural Secants, and consequently the meridional Parts, increase much faster; and to make it more intelligible, we shall have recourse to that excellent Book, intituled *Correction of Errors in Navigation*, written by the ingenious Mr *Edward Wright*, the first Inventor of the Projection we are now treating of, and of the Table of meridional Parts, by which it is projected, and the Operations therein performed. According to his Table of Latitudes (being of the same Construction and Use, with those we now call Tables of meridional Parts) and Mr *Sherwin*'s or any correct Table of natural Secants, we shall find, by the continual Addition of the Secant of the succeeding Minute, to the meridional Parts of the Minute proposed, the Sum is the meridional parts of the said succeeding Minute, &c. as above, and as in the following Instances in finding the meridional parts to higher Latitudes.

EXAMPLE.

	D.	M.	
The Meridional Parts of —	79	20 is	81540915
Secant of the next Minute *viz.*	79	21	54109
Meridional Parts of —— ——	79	21	81595024
Secant of —— ——	79	22	54193
Meridional Parts of ——	79	22	81649217
Add the Secant of —— ——	79	23	54277
Meridional Parts of ——	79	23	81703494
Add Secant of —— ——	79	24	54362
Meridional Parts of ——	79	24	81757856
Add Secant of —— ——	79	25	54446
Meridional Parts of ——	79	25	81812302

IN this manner (not to proceed any further by way of Example) are all the meridional Parts, from 00 *deg.* 00 *min.* to 89 *deg.* 59 *min.* produced, it

it being impossible to produce the Meridional Parts, of 90 *deg.* 00 *min.* because it's Secant is infinite, and in the Projection it is impossible to represent the Pole, because upon the Globe, the Meridians incline, and at last concur in the Pole; but in the Projection, the Meridians, being parallel to each other, could not, in the greatest imaginable Space, concur in a Point, and yet without such a Concurrence of the Meridian, it is impossible to form or imagine a Pole or Poles to the Globe; however that Difficulty is obviated, when we consider that these Tables of meridional Parts approach much nearer the Poles, than any Navigation is practicable, and therefore do fully answer the End for which they were intended.

BUT tho' Mr *Wright* in his Table of Latitudes (and we after him in this Example) have inserted the meridional Parts to so many places, yet it is thought sufficiently exact for Practice to cast away the last four Figures towards the right Hand; and use the rest; only if the first towards the left Hand of those cut off, be above a 5 add 1 to the right Hand Figure of those reserved for use and thus are the meridional Parts produced, that are in *Seller*'s Navigation, *Wilson*'s Navigation, and other Practical Books; as for Instance, Mr *Wright* makes the meridional Parts for 19 *deg.* 12 *min.* to be 11741560, but these Authors cutting off four Figures towards the right Hand, make it only 1174. But Mr *Wright* making the Meridian Parts of 79 *deg.* 24 *min.* to be 81757856, if four Figures towards the right Hand were cut off, without any regard to the first towards the left Hand of those so cut off, the Figures reserved for use would be 8175, but the next Figure being above 5, *viz.* 7, these Authors add 1, to the last Figure, which is 5, and the meridional Parts for 79 *deg.* 24 *min.* is 8176; I shall only

add, that the greater number of places that the meridional Parts are calculated to, they are more exact, but they are sufficiently so for Practice, when those four places towards the right Hand are cut off, the Error contracted thereby (if any at all) not being perceptible.

BUT notwithstanding what has been said, as to the abridging the number of Figures in the meridional Parts, it is adviseable, in the composing them by the addition of Secants, that the Secants made use of for that purpose, do not consist of a number of places, less than five at least.

BUT if a Table of meridional Parts, be made but to every other Minute as 0, 2, 4, 6, *&c.* Minutes above every Degree, add the Secants of the two succeeding Minutes to the Meridional Parts, found for the Minute proposed, the Sum is the meridional Parts of the next Minute but one.

EXAMPLE.

	D.	M.	
Meridional Parts for ———	63	26	49630758
Secant of ——— ———	63	27	22372
Secant of ——— ———	63	28	22385
Meridional Parts for ———	63	28	49675515

THIS is so easy, that it needs no more *Examples.*

AND to find the meridional Parts of the intermediate Minute 63 27. The meridional parts, for 63 26 (using only the first four Figures) is 4963, and for 63 28, the meridional Parts is 4967, the Difference is 4, the half of which, 2, added to the least, *viz.* 4963, the meridional parts of 63 26, the Sum 4965 is the meridional parts of 63 27 required, and the Difference being so small, may be readily done by the mind without the help of Pen and Ink.

FROM this Construction the following Table of meridional Parts is calculated.

A TABLE

A TABLE OF MERIDIONAL PARTS, OR MILES To every other Minute of the MERIDIAN.

A Table of Meridional Parts.

Min.	D. 0	D. 1	D. 2	D. 3	D. 4	D. 5	D. 6	D. 7
0	0	60	120	180	240	300	361	421
2	2	62	122	182	242	302	363	423
4	4	64	124	184	244	304	365	425
6	6	66	126	186	246	306	367	427
8	8	68	128	188	248	308	369	429
10	10	70	130	190	250	310	371	431
12	12	72	132	192	252	312	373	433
14	14	74	134	194	254	314	375	435
16	16	76	136	196	256	316	377	437
18	18	78	138	198	258	318	379	439
20	20	80	140	200	260	320	381	441
22	22	82	142	202	262	322	383	443
24	24	84	144	204	264	324	385	445
26	26	86	146	206	266	326	387	447
28	28	88	148	208	268	328	389	449
30	30	90	150	210	270	330	391	451
32	32	92	152	212	272	332	393	453
34	34	94	154	214	274	334	395	455
36	36	96	156	216	276	336	397	457
38	38	98	158	218	278	338	399	459
40	40	100	160	220	280	340	401	461
42	42	102	162	222	282	342	403	463
44	44	104	164	224	284	344	405	465
46	46	106	166	226	286	346	407	467
48	48	108	168	228	288	348	409	469
50	50	110	170	230	290	350	411	471
52	52	112	172	232	292	352	413	473
54	54	114	174	234	294	354	415	475
56	56	116	176	236	296	356	417	477
58	58	118	178	238	298	358	419	479

A Table of Meridional Parts.

Min.	D. 8	D. 9	D. 10	D. 11	D. 12	D. 13	D. 14	D. 15
0	481	542	603	664	725	787	848	910
2	483	544	605	666	727	789	850	912
4	485	546	607	668	729	791	852	914
6	488	548	609	670	731	793	855	917
8	490	550	611	672	733	795	857	919
10	492	552	613	674	735	797	859	921
12	494	554	615	676	737	799	861	923
14	496	556	617	678	740	801	863	925
16	498	558	619	680	742	803	865	927
18	500	560	621	682	744	805	867	929
20	502	562	623	684	746	807	869	931
22	504	564	625	686	748	809	871	933
24	506	566	627	688	750	811	873	935
26	508	568	629	690	752	813	875	937
28	510	570	631	692	754	815	877	939
30	512	573	633	695	756	817	879	941
32	514	575	635	697	758	820	881	944
34	516	577	638	699	760	822	883	946
36	518	579	640	701	762	824	886	948
38	520	581	642	703	764	826	888	950
40	522	583	644	705	766	828	890	952
42	524	585	646	707	768	830	892	954
44	526	587	648	709	770	832	894	956
46	528	589	650	711	772	834	896	958
48	530	591	652	713	774	836	898	960
50	532	593	654	715	776	838	900	962
52	534	595	656	717	778	840	902	964
54	536	597	658	719	781	842	904	966
56	538	599	660	721	783	844	906	968
58	540	601	662	723	785	846	908	971

A Table of Meridional Parts.

Min.	*Deg.* 16	*Deg.* 17	*Deg.* 18	*Deg.* 19	*Deg.* 20	*Deg.* 21
0	973	1035	1098	1161	1225	1289
2	975	37	1100	63	27	91
4	977	39	02	66	29	93
6	979	41	04	68	31	96
8	981	44	07	70	34	98
10	983	1046	1109	1172	1236	1300
12	985	48	11	74	38	02
14	987	50	13	76	40	04
16	989	52	15	78	42	06
18	991	54	17	80	44	08
20	993	1056	1119	1183	1246	1311
22	996	58	21	85	48	13
24	998	60	23	87	51	15
26	1000	62	25	89	53	17
28	02	64	28	91	55	19
30	1004	1067	1130	1193	1257	1321
32	06	69	32	95	59	23
34	08	71	34	97	61	26
36	10	73	36	1200	63	28
38	12	75	38	02	66	30
40	1014	1077	1140	1204	1268	1332
42	16	79	42	06	70	34
44	18	81	44	08	72	36
46	21	83	47	10	74	38
48	23	85	49	12	76	41
50	1025	1088	1151	1214	1278	1343
52	27	90	53	16	81	45
54	29	92	55	19	83	47
56	31	94	57	21	85	49
58	33	96	59	23	87	51

A Table of Meridional Parts.

Min.	*Deg.* 22	*Deg.* 23	*Deg.* 24	*Deg.* 25	*Deg.* 26	*Deg.* 27
0	1354	1419	1484	1550	1616	1683
2	56	21	86	52	19	86
4	58	23	88	54	21	88
6	60	25	91	57	23	90
8	62	27	93	59	25	92
10	1364	1429	1495	1561	1628	1695
12	67	31	97	63	30	97
14	69	34	99	65	32	99
16	71	36	1501	68	34	1701
18	73	38	03	70	36	04
20	1375	1440	1506	1572	1639	1706
22	77	42	08	74	41	08
24	79	45	10	76	43	10
26	82	47	12	79	45	13
28	84	49	15	81	48	15
30	1386	1451	1517	1583	1650	1717
32	88	53	19	85	52	19
34	90	56	21	87	54	22
36	92	58	23	90	57	24
38	95	60	26	92	59	26
40	1397	1462	1528	1594	1661	1728
42	99	64	30	96	63	31
44	1401	66	32	99	65	33
46	03	69	34	1601	68	35
48	05	71	37	03	70	37
50	1408	1473	1539	1605	1672	1740
52	10	75	41	07	74	42
54	12	77	43	10	77	44
56	14	80	45	12	79	47
58	16	82	48	14	81	49

A Table of Meridional Parts.

Min.	Deg. 28	Deg. 29	Deg. 30	Deg. 31	Deg. 32	Deg. 33
0	1751	1819	1888	1958	2028	2099
2	53	22	91	60	31	2102
4	56	24	93	63	33	04
6	58	26	95	65	35	07
8	60	28	98	67	38	09
10	1762	1831	1900	1970	2040	2111
12	65	33	02	72	42	14
14	67	35	04	74	45	16
16	69	38	07	77	47	19
18	71	40	09	79	50	21
20	1774	1842	1911	1981	2052	2123
22	76	45	14	84	54	26
24	78	47	16	86	57	28
26	81	49	18	88	59	31
28	83	51	21	91	61	33
30	1785	1854	1923	1993	2064	2135
32	87	56	25	95	66	38
34	90	58	28	98	69	40
36	92	61	30	2000	71	43
38	94	63	32	02	73	45
40	1797	1865	1935	2005	2076	2147
42	99	68	37	07	78	50
44	1801	70	39	09	80	52
46	03	72	42	12	83	55
48	06	74	44	14	85	57
50	1808	1877	1946	2017	2088	2159
52	10	79	49	19	90	62
54	12	81	51	21	92	64
56	15	84	53	24	95	67
58	17	86	56	26	97	69

A Table of Meridional Parts.

Min.	*Deg.* 34	*Deg.* 35	*Deg.* 36	*Deg.* 37	*Deg.* 38	*Deg.* 39
0	2171	2244	2318	2393	2468	2545
2	74	47	20	95	71	47
4	76	49	23	98	73	50
6	79	52	25	2400	76	52
8	81	54	28	03	78	55
10	2183	2256	2330	2405	2481	2558
12	86	59	33	08	83	60
14	88	61	35	10	86	63
16	91	64	38	13	89	66
18	93	66	40	15	91	68
20	2196	2269	2343	2418	2494	2571
22	98	71	45	20	96	73
24	2200	74	48	23	99	76
26	03	76	50	25	2501	78
28	05	78	53	28	04	81
30	2208	2281	2355	2430	2506	2584
32	10	83	58	33	09	86
34	13	86	60	35	12	89
36	15	88	63	38	14	91
38	17	91	65	40	17	94
40	2220	2293	2368	2443	2519	2597
42	22	96	70	45	22	99
44	25	98	73	48	24	2602
46	27	2301	75	50	27	04
48	30	03	77	53	29	07
50	2232	2306	2380	2456	2532	2610
52	34	08	83	58	35	12
54	37	11	85	61	37	15
56	39	13	88	63	40	17
58	42	15	90	66	42	20

A Table of Meridional Parts.

Min.	Deg. 40	Deg. 41	Deg. 42	Deg. 43	Deg. 44	Deg. 45
0	2623	2702	2782	2863	2946	3030
2	25	04	84	66	49	33
4	28	07	87	69	51	36
6	30	10	90	71	54	38
8	33	12	92	74	57	41
10	2636	2715	2795	2877	2960	3044
12	38	17	98	80	63	47
14	41	20	2801	82	65	50
16	44	22	03	85	68	53
18	46	25	06	88	71	55
20	2649	2728	2809	2890	2974	3058
22	51	31	11	93	76	61
24	54	33	14	96	79	64
26	57	36	17	99	82	67
28	59	39	20	2902	85	70
30	2662	2741	2822	2904	2988	3073
32	65	44	25	07	90	75
34	67	47	28	10	93	78
36	70	49	30	13	96	81
38	73	52	33	15	99	84
40	2675	2755	2836	2918	3002	3087
42	78	58	39	21	05	90
44	80	60	41	24	07	93
46	83	63	44	26	10	95
48	86	66	47	29	13	98
50	2688	2768	2849	2932	3016	3101
52	91	71	52	35	19	04
54	94	74	55	37	22	07
56	96	76	58	40	24	10
58	99	79	60	43	27	13

A Table of Meridional Parts.

Min.	Deg. 46	Deg. 47	Deg. 48	Deg. 49	Deg. 50	Deg. 51
0	3116	3203	3292	3382	3475	3569
2	18	06	95	85	78	72
4	21	09	98	88	81	75
6	24	12	3301	91	84	78
8	27	15	04	94	87	82
10	3130	3217	3307	3397	3490	3585
12	33	20	10	3400	93	88
14	36	23	13	03	96	91
16	39	26	16	07	99	94
18	42	29	19	10	3503	98
20	3144	3232	3322	3413	3506	3600
22	47	35	25	16	09	04
24	50	38	28	19	12	07
26	53	41	31	22	15	10
28	56	44	34	25	18	14
30	3159	3247	3337	3428	3521	3617
32	62	50	40	31	25	20
34	65	53	43	34	28	23
36	68	56	46	37	31	26
38	71	59	49	40	34	30
40	3773	3262	3352	3443	3537	3633
42	76	65	55	46	40	36
44	79	68	58	49	43	39
46	82	71	61	53	47	43
48	85	74	64	56	50	46
50	3188	3277	3367	3459	3553	3649
52	91	80	70	62	56	52
54	94	83	73	65	59	56
56	97	86	76	68	62	59
58	3200	89	79	71	66	62

A Table of Meridional Parts.

Min.	Deg. 52	Deg. 53	Deg. 54	Deg. 55	Deg. 56	Deg. 57
0	3665	3764	3865	3968	4074	4183
2	69	68	69	72	78	86
4	72	72	72	75	81	90
6	75	75	75	78	85	94
8	78	78	78	82	88	97
10	3682	3780	3882	3986	4092	4201
12	85	84	85	89	96	05
14	88	87	89	93	4100	09
16	91	91	92	96	03	12
18	95	94	95	4000	06	16
20	3698	3797	3899	4003	4110	4220
22	3701	3801	3902	07	14	23
24	05	04	06	10	17	27
26	08	07	09	14	21	32
28	11	11	13	17	24	35
30	3714	3814	3916	4021	4128	4238
32	18	17	20	24	32	42
34	21	21	23	28	35	46
36	24	24	26	31	39	49
38	28	27	30	35	43	53
40	3731	3831	3933	4038	4146	4257
42	34	34	37	42	50	61
44	38	37	40	46	54	64
46	41	41	44	49	57	68
48	44	44	47	53	61	72
50	3747	3848	3951	4056	4164	4276
52	51	51	54	60	68	79
54	54	55	58	63	72	83
56	57	58	61	67	75	87
58	60	61	65	70	79	91

A Table of Meridional Parts.

Min.	Deg. 58	Deg. 59	Deg. 60	Deg. 61	Deg. 62	Deg. 63
0	4294	4409	4528	4649	4775	4905
2	98	13	32	54	80	10
4	4302	17	36	58	84	14
6	06	21	40	62	88	19
8	10	25	44	66	92	23
10	4313	4429	4548	4670	4797	4927
12	17	33	52	74	4801	32
14	21	37	56	78	05	36
16	25	41	60	83	10	41
18	29	45	64	87	14	45
20	4332	4448	4568	4691	4818	4950
22	36	52	72	95	22	54
24	40	56	76	99	27	59
26	44	60	80	4704	31	63
28	48	64	84	08	35	67
30	4352	4468	4588	4712	4840	4972
32	55	72	92	16	44	76
34	59	76	96	20	48	81
36	63	80	4600	24	53	85
38	67	84	04	29	57	90
40	4371	4488	4608	4733	4861	4994
42	75	92	13	37	66	99
44	78	96	17	41	70	5003
46	82	4500	21	46	75	08
48	86	04	25	50	80	12
50	4390	4508	4629	4754	4883	5017
52	94	12	33	58	88	22
54	98	16	37	63	92	26
56	4402	20	41	67	96	31
58	05	24	45	71	4901	35

A Table of Meridional Parts.

Min.	Deg. 64	Deg. 65	Deg. 66	Deg. 67	Deg. 68	Deg. 69
0	5040	5179	5324	5474	5631	5795
2	44	84	29	80	37	5801
4	49	89	34	85	42	06
6	53	93	39	90	47	12
8	58	98	44	95	53	18
10	5063	5203	5349	5500	5658	5823
12	67	08	54	05	64	29
14	72	12	59	10	69	34
16	78	17	64	15	74	40
18	81	22	69	20	80	46
20	5086	5227	5373	5526	5685	5851
22	90	32	78	31	91	57
24	95	36	83	37	96	63
26	5100	41	88	42	5701	68
28	04	46	93	47	07	74
30	5109	5251	5398	5552	5712	5880
32	14	56	5403	57	18	86
34	18	61	09	63	23	91
36	23	65	14	68	29	97
38	27	70	19	73	34	5903
40	5132	5275	5424	5578	5740	5909
42	37	80	29	84	45	14
44	42	85	34	89	51	20
46	46	90	39	94	56	26
48	51	95	44	99	62	32
50	5156	5299	5449	5605	5767	5937
52	60	5304	54	10	73	43
54	65	09	59	15	78	49
56	70	14	64	21	84	55
58	74	19	69	26	90	61

A Table of Meridional Parts.

Min.	Deg. 70	Deg. 71	Deg. 72	Deg. 73	Deg. 74	Deg. 75
0	5967	6146	6336	6535	6747	6971
2	72	53	42	42	54	79
4	78	59	49	49	61	87
6	84	65	55	56	69	95
8	90	71	62	63	76	7003
10	5996	6177	6368	6570	6783	7010
12	6002	83	75	77	91	18
14	08	90	81	84	98	26
16	14	96	88	90	6805	34
18	20	6202	94	97	13	42
20	6026	6208	6401	6605	6820	7050
22	32	15	08	11	27	58
24	38	21	14	18	35	65
26	43	27	21	25	42	73
28	49	34	27	32	50	81
30	6055	6240	6434	6639	6857	7089
32	61	46	41	47	65	97
34	67	52	47	54	72	7105
36	73	59	54	61	80	13
38	79	65	61	68	87	21
40	6085	6271	6468	6675	6895	7130
42	92	78	74	82	6903	38
44	98	84	81	89	10	46
46	6104	91	88	96	18	54
48	10	97	94	6703	25	62
50	6116	6303	6501	6711	6933	7170
52	22	10	08	18	41	78
54	28	16	15	25	48	87
56	34	23	22	32	56	95
58	40	29	28	39	64	7203

A Table of Meridional Parts.

Min.	*Deg.* 76	*Deg.* 77	*Deg.* 78	*Deg.* 79	*Deg.* 80	*Deg.* 81
0	7211	7469	7746	8047	8377	8741
2	20	78	56	58	89	54
4	28	86	65	69	8400	67
6	36	95	75	79	12	80
8	45	7504	85	89	24	93
10	7253	7513	7795	8100	8435	8806
12	61	22	7804	11	47	19
14	70	31	14	22	59	32
16	78	40	24	32	71	45
18	87	50	34	43	83	59
20	7295	7559	7844	8154	8494	8872
22	7303	68	54	65	8506	85
24	12	77	64	76	18	98
26	20	86	74	87	30	8912
28	29	95	84	98	42	25
30	7338	7605	7894	8208	8555	8939
32	46	14	7904	19	67	52
34	55	23	14	31	79	66
36	63	32	24	42	91	80
38	72	42	34	53	8603	93
40	7381	7651	7944	8264	8616	9007
42	89	61	14	75	28	21
44	98	70	65	86	41	35
46	7407	79	75	98	53	49
48	16	89	85	8309	65	63
50	7424	7698	7995	8320	8678	9077
52	33	7708	8006	31	91	91
54	42	17	16	43	8703	9105
56	51	27	27	54	16	20
58	60	37	37	66	29	34

A Table of Meridional Parts.

Min.	Deg. 82	Deg. 83	Deg. 84	Deg. 85	Deg. 86
0	9148	9609	10148	10770	11539
2	63	25	160	793	568
4	77	42	179	816	597
6	92	59	199	839	626
8	9206	75	218	863	656
10	9221	9692	10238	10886	11686
12	36	9709	258	910	716
14	50	26	278	934	746
16	65	43	298	958	777
18	80	60	318	983	808
20	9295	9777	10338	11007	11839
22	9310	95	358	032	870
24	25	9812	378	058	902
26	40	30	399	082	934
28	56	47	420	107	967
30	9371	9865	10441	11133	11999
32	86	82	462	158	032
34	9402	9900	483	184	066
36	17	18	504	210	099
38	33	36	526	236	133
40	9449	9954	10547	11263	12167
42	64	73	569	289	202
44	80	9992	590	316	237
46	96	10009	612	343	273
48	9512	028	634	371	308
50	9528	10046	10656	11398	12344
52	44	065	679	426	381
54	60	084	701	454	408
56	76	103	724	482	445
58	93	122	747	510	483

A Table of Meridional Parts.

Min.	*Deg.* 87	*Deg.* 88	*Deg.* 89
0	12521	13920	16317
2	559	978	435
4	598	14037	557
6	638	097	683
8	678	158	814
10	12718	14220	16950
12	759	284	17092
14	800	348	240
16	842	414	394
18	884	481	556
20	12027	14550	17726
22	970	619	904
24	13014	691	18093
26	059	764	292
28	104	838	503
30	13150	14914	18729
32	196	992	971
34	243	15071	19230
36	294	152	511
38	339	236	817
40	13388	15322	20152
42	437	409	524
44	488	499	941
46	539	591	21416
48	591	686	967
50	13643	15783	22623
52	697	409	23435
54	751	499	24499
56	807	591	26046
58	863	686	28911

AND now according to my promise, Page 868, I shall exhibit a Method of making a Scale to measure Distances on the *Mercator*'s Chart, which may by the following Example be made for any Chart, if the extreme Latitudes of the Chart be given.

Example. Let it be required to make a Scale for a *Mercator*'s Chart from Latitude 32 to Latitude 50, either North or South, and to contain 100 Leagues or 300 Miles Distance. (*See Plate* XI. *Fig.* D.)

FIRST, find the Length of 300 Miles in the least Latitude (which here is 32) thus, As Sine Comp. Lat. 32°, To Radius; So is 300 Miles (the length of your Scale) To 354′ or 5° 54′, which taken off the graduated line of Longitude, let it be the Length of the lowest line of the Scale 32 32, upon the middle of which line (at 50) raise the Perpendicular 50.50, substract the Natural Secant of the least Latitude 32°, from the Natural Secant of the greatest Latitude 50°, and the Remainder 3766 taken from a Scale of equal Parts, set from 50 to 50 upwards upon the foresaid Perpendicular; and thro' 50 draw the uppermost line at right Angles with the perpendicular, and Parallel to the bottom line 32.32, that line represents the Parallel of 50°. Then having found by the foregoing Proportion the length of 300 Miles, in Latitude 50°, which is 467′, or 7° 47′; take half thereof, *viz.* 3° 53′½ from the graduated line of Longitude, and set it both ways upon the foresaid Parallel of 50, from the middle of the line (where it is cut by the Perpendicular) to each end; so shall the distance between those two Marks be the Measure of 300 Miles in Lat. 50°. Then from the Extremities of the Top and Bottom lines, draw the Side lines, 50 32 and 50 32. Now to find the intermediate Parallels, substract the Na-

tural Secant of the leaſt Latitude 32, from the Natural Secant of each greater Latitude as 34 36 38, &c. to 50, the ſeveral Remainders taken in your Compaſſes from the ſame Scale of equal Parts, by which you meaſured the middle perpendicular line, and ſet upon the ſame line from the line 32.32 upwards, ſhall determine the points in that line thro' which the ſeveral Parallels muſt paſs; therefore thro' theſe Marks draw lines parallel to the line 32.32, they repreſent the ſeveral Parallels required. Then divide the uppermoſt and loweſt Parallel each into 100 equal Parts, marking them both with 10, 20, 30, &c. and between thoſe Diviſions marked with the ſame Number, on each line, draw ſtrait lines thro' the Scale; theſe Lines will alſo divide each Parallel into 100 equal Parts or Leagues upon which you may meaſure your Diſtance in any Parallel as before is taught.

THE uſe of the Scale is eaſy, the Diſtances being to be taken off according to the Latitude of that part of the Chart, which is to be meaſured thus, the line 32.32, is 100 Leagues or 300 Miles in the Parallel 32, and the line 50.50, is 300 Miles in the Parallel of 50 Degrees: But if (as is moſt common) the Ship ſails upon an oblique Courſe, meaſure the Diſtance upon a parallel in the Scale that is neareſt the middle parallel, between the two Extremes, and that is ſufficiently exact.

Example. If the Ship has ſailed in the North-Eaſt quarter from Latitude 42, to Latitude 46, the Diſtance is to be meaſured on that parallel of the Scale marked 44.44, &c.

CHAP.

CHAP. XL.

Of the chief Problem in Navigation; viz. *To find in the Maps the Place to which a Ship is come after some sailing; or to find the Latitude and Longitude of that Place.*

PROPOSITION I.

The Point to which a Ship is to be directed, cannot be known except we first know what Place the Ship is come to.

WE said, in the preceding Proposition, that the chief Problem in Navigation is how to find the Point to which a Ship is to be directed; and which 'tis plain cannot be known except we first know the Place from which the Ship is to be directed; and therefore the Solution of that Problem for finding the Ship's Place is necessary: and the Problem for finding the Point comes to this.

PROPOSITION II.

To find the Place to which a Ship is come after some time of sailing.

THE *Dutch* mark every Day with a Pin the Place in the Maps to which the Ship is come; and thence they may know which way to steer the Ship: and for this they use a three-fold Method, according to that which they judge is found most exactly.

Having obſerved the Point the Ship ſailed on the former Day, and the Way ſhe hath made ſince, her preſent Place is thus found in the Maps: Take a Square, and apply one Leg to the Place from which the Ship came laſt, and the other to the Point or Line neareſt it, on which the Ship ſailed, and mark with a Pin, or Pen, the part of the Leg, which is above the place left. Then take, from a Scale of Miles, the Miles run, and apply one Foot of the Compaſs to the Place left, and let the Scale be moved in the Line that ſhows the Point, 'till the other Foot reach the Point marked on the Square; the Place in the Map under that Point, in that Situation of the Square, is the Ship's Place.

SEAMEN uſe two pair of Compaſſes without a Square; but if you would determine the Ship's Place more accurately by Calculation; the Problem will be this: Having the Latitude and Longitude of the Place left, and the point ſailed on, with the Diſtance ſailed, to find the Latitude and Longitude of the Place come to; by which the Ship's Place may be marked more accurately in the Map.

2. THE Point the Ship hath ſailed on, and the Latitude ſhe is come to, being known; to find her Place in the Map.

LET there be again applied one Leg of the Square, to the Point ſailed on, or one neareſt it, and the other laid on the Place come from, and there make a mark with a Pin or Pen; then move the Leg applied to the Point ſailed on, 'till the marked Point on the other Leg come into the Parallel of the obſerved Latitude; and the Point where it cuts it, is the Ship's Place. If there be not a Parallel drawn thro' it, take with the Compaſſes the Degrees on the Margin between the next Parallel, and that Latitude; and at the ſame Time apply a

Square

Square in the Line of the Points, and ſetting one Foot on ſome Place of the Parallel, ſo as it's other may reach to the other Point, marked on the Leg, you have the Ship's Place. Or by Calculation the Problem is this: Having the Latitude and Longitude of the Place left, and the Latitude of the Place come to, and the Point ſailed in, to find the Longitude which will give the Ship's Place.

3. KNOWING the Diſtance ſailed, and the Latitude come to, to find the Ship's Place in the Map.

TAKE from the Scale, the Miles ſailed, and if a Parallel paſs thro' the Degree of Latitude, known by Obſervation; place one Foot of the Compaſſes on the Place known, and the other on the Parallel, and you have the Ship's Place: but if no Parallel paſs thro' it, apply one Leg of the Square to the next Parallel, and on the other Leg mark the Degree of Latitude, and move the Square 'till the other Foot of the Compaſs touch the Point marked on the Ruler: the Place of the Map under that Point is the Ship's Place. By Calculation the Problem is this: Having the Latitude and Longitude of one Place, and the Diſtance of it from another, and the Latitude of that other; to find alſo it's Longitude, which will determine it's Situation on the Globe. There is a fourth Method alſo by having the Longitude of the Place come to, when it's Latitude is wanted; but becauſe that ſeldom happens at Sea, we ſhall omit it. They that deſire more of this, may read *Snellius*, *Stevinus*, *Metius*, and others, who have handled it largely.

PRO-

PROPOSITION III.

To find nearly the Point a Ship sails in, tho' the Signs are fallacious.

IN the Solution of the former Propoſition there was ſuppoſed, as known; (1) The Point ſailed on, (2) The Diſtance ſailed, (3) The Latitude of the Place come to: Now we are to ſhow how theſe three are found at Sea: for if theſe are not found truly, the Ship's Place is not truly determined.

1. AS to the Point ſailed on, Sailors know it by their Sea-Compaſs; for the Ship is ſuppoſed to deſcribe the ſame Line that ſhows the Point. They ſeldom uſe the Method by the Place of the Sun's riſing or ſetting by Calculation.

THESE Signs are ſubject to uncertainty; 1. If the Declination of the Needle be not known in that Place. 2. If there be a Current there, or as in many Places in the *Torrid Zone*, a general and conſtant Motion of the Sea, that will carry the Ship with it. 3. A Storm will drive the Ship out of the Line of Direction. 4. The Ebbing and Flowing of the Sea will carry the Ship with it. 5. Allowance is to be made for Lee-Way, on account of the Waves that hinder the Ship's Motion that Way ſhe is directed; for all which Reaſons their Sea-Compaſs is not to be relied on, and the Correction of theſe is very imperfect.

PROPOSITION IV.

To find how many Miles the Ship hath ſailed from a given Place.

THIS is but gueſſed at; 1. By knowing how far a Ship will ſail in ſuch a Time, with ſuch a Wind.

2. If

2. If she sail in the same Meridian, or near it, the Difference of the Latitude of the Place left and come to, turned to Miles, gives the Distance sailed with that Wind, in that Time; and then the Ship sailing any other Way with that Wind makes the same Way in that Time. 3. With more Labour they find it by the Log-line, which is a Line fastened to a Log of Wood, and thrown out of the Ship's Stern, the Line being wound about a Wheel in the Ship's Cabin, which must turn to give more Rope while the Ship moves from the Log; they observe how many marked Fathoms of the Rope go out of the Ship in half a Minute, which will give her Motion in sixty Minutes, or one hundred and twenty Minutes and a half; each Mark that goes out will be a Mile in an Hour, if the Marks or Knots be fifty Foot distant. But these Methods are uncertain; for, 1. There is a Motion of the Sea in some Places to one Place, to which, if the Ship go, she moves the faster; if to the contrary, slower. 2. The Ship is carried by other Causes to other Points, and goes in several Lines. 3. The Winds frequently change. 4. The higher the Ship's Stern is, the Line winds off the Wheel the slower, and her Motion thereby seems the less.

PROPOSITION V.

To observe the Latitude of the Place come to.

THEY use the Sun by Day, and the Stars by Night, as in *Chap.* 23. They use three Sorts of Instruments for this Purpose, *viz.* an Astrolabe, Radius, and Triangle. The Latitude by these is determined more accurately than the Point sailed in, or the Miles sailed; tho' there is also an uncertainty on account of, first, the Ship's Motion, which hinders Observation; secondly, not apply-

ing the Eye right to the Instrument; and, thirdly, the Refraction is not considered.

PROPOSITION VI.

From what precedes it appears, that the Methods which Sailors use to find the Ship's Place, are in the Chart uncertain, on account of the Uncertainty as to the Point sailed in, and of the Miles run, and of the observed Latitude; yet the Observation of the Latitude of the Place come to, is less liable to Error, especially in calm Weather, and a clear Sky, and may be corrected.

BUT from this alone we cannot find the Ship's Place, but, as was at large delivered, in *Chap.* xxx. there must be another Datum, *viz.* either the Distance from the Place left, or Point sailed in, or the Difference of the Longitude left, and come to; and therefore the Longitude of the Place come to, which, with the Latitude, is again wanted, determines the Ship's Place.

HENCE it appears, that the Art of Navigation is to be perfected by the Solution of this Problem; *To find, at any Time, the Longitude of a Place at Sea.* A public Reward is promised for the Discovery; let him obtain it who is able.

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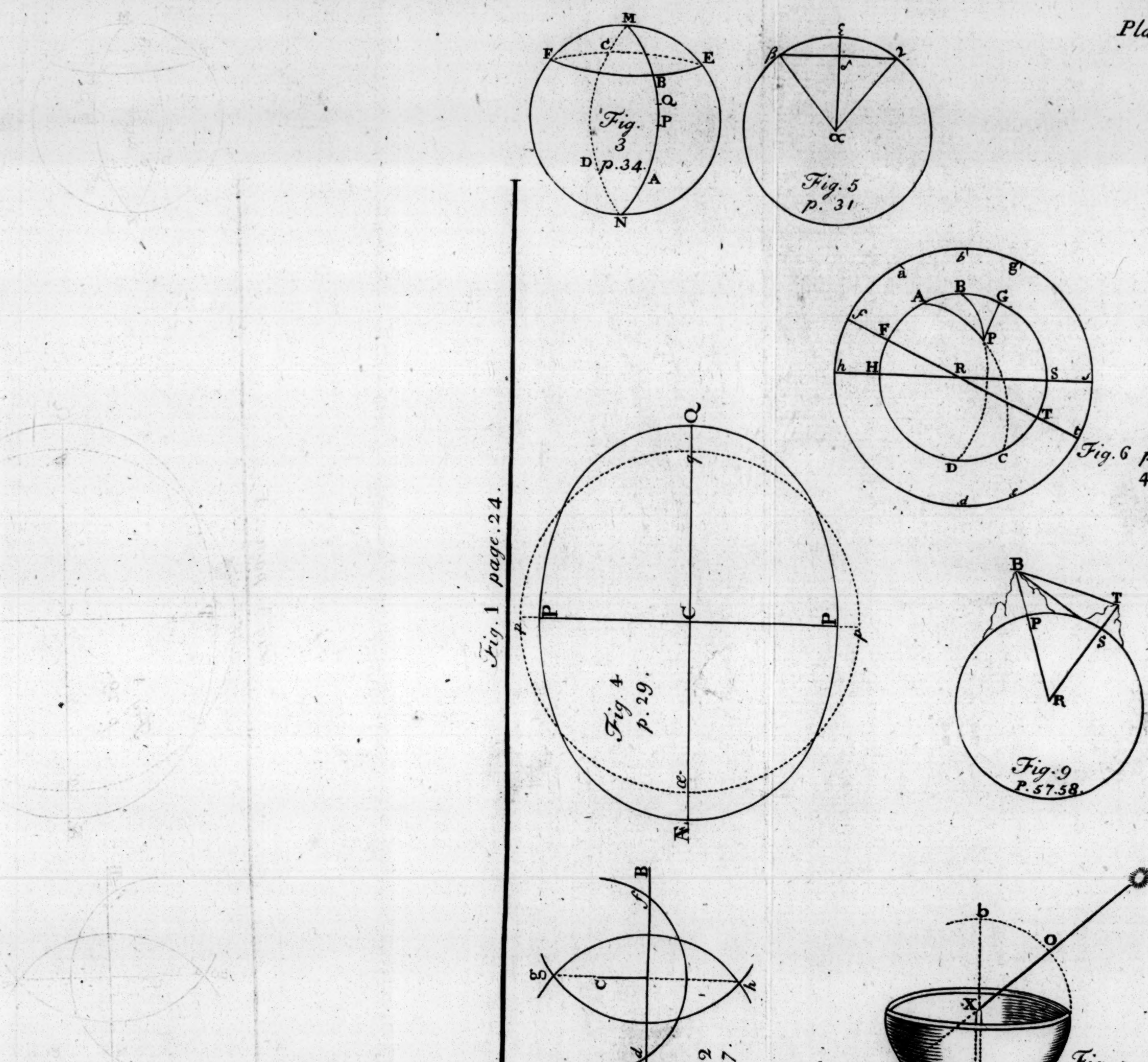
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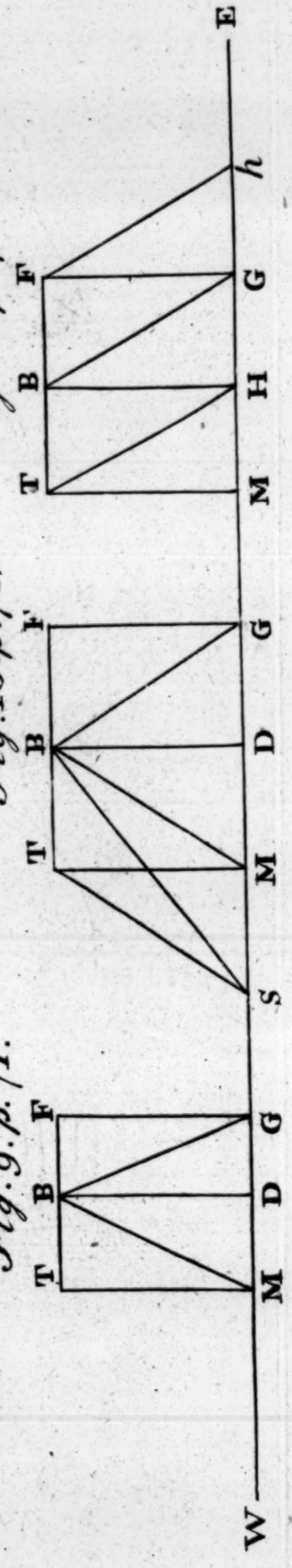

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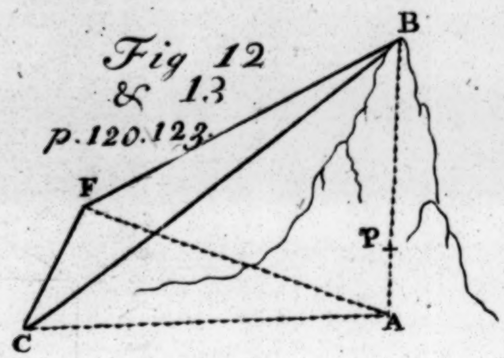

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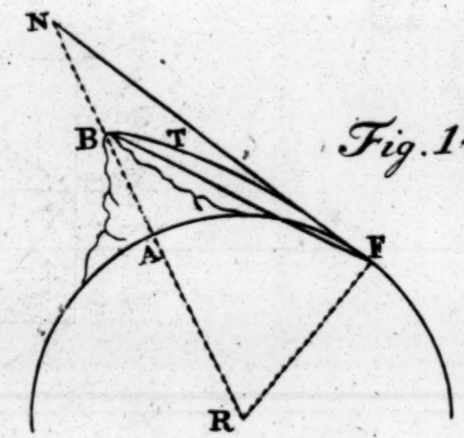

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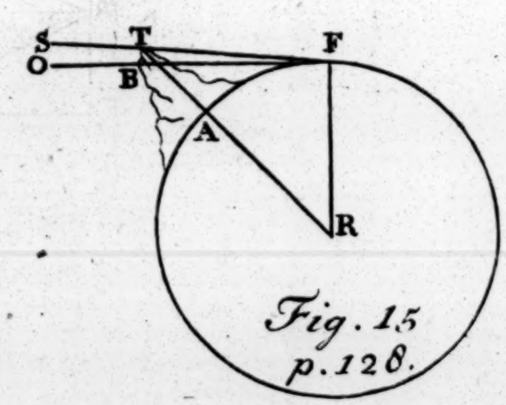

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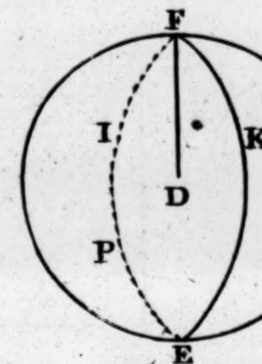

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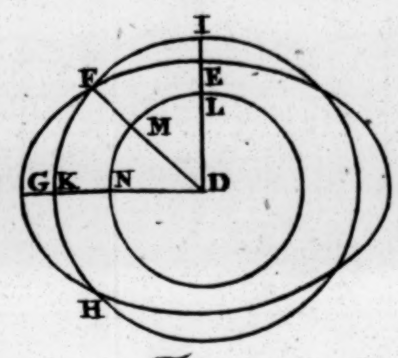

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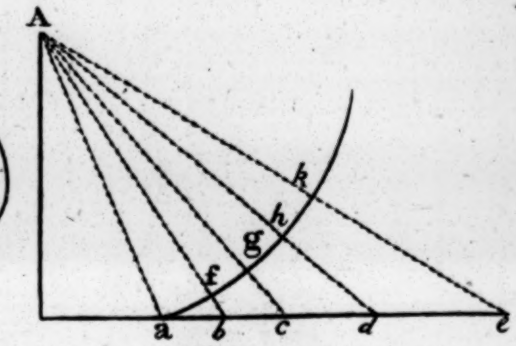

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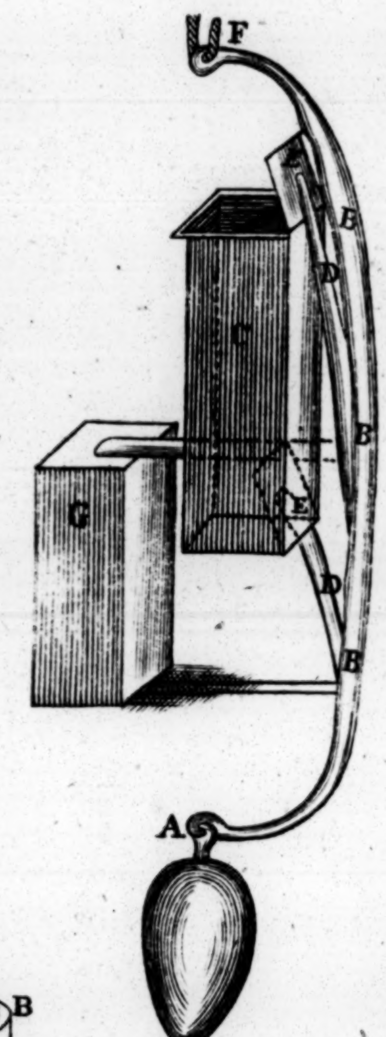

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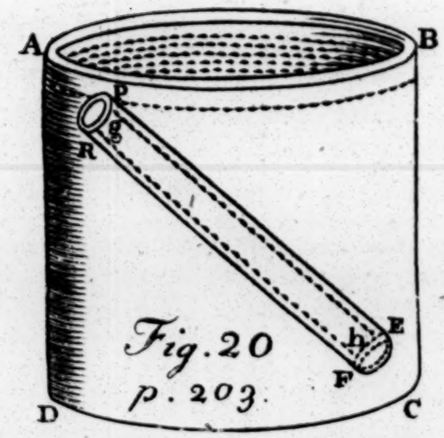

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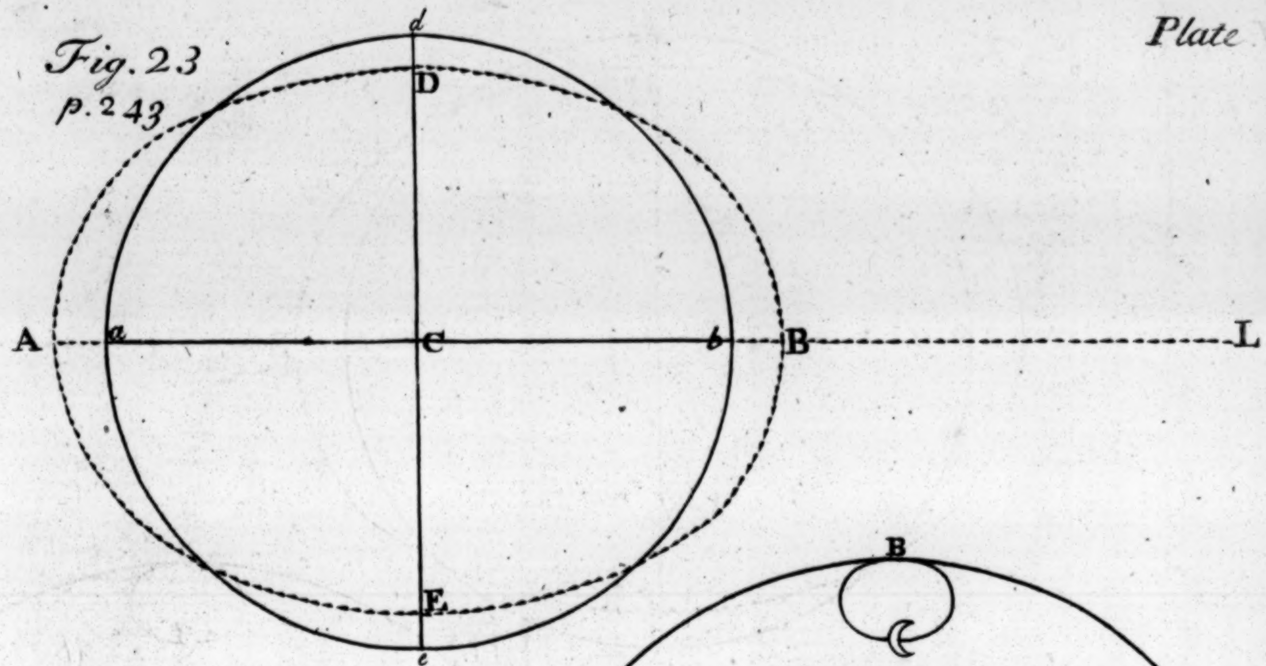

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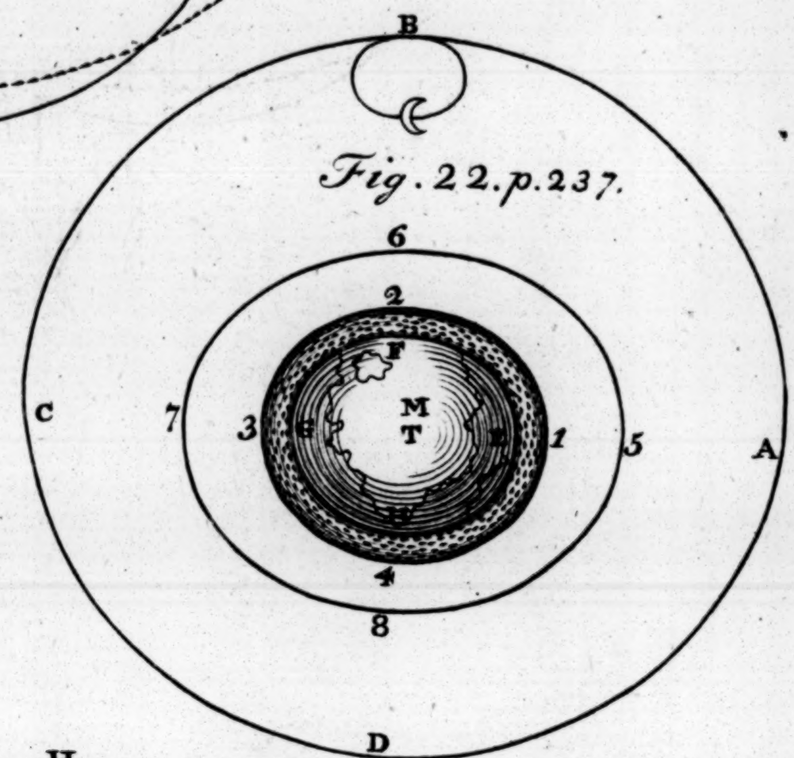

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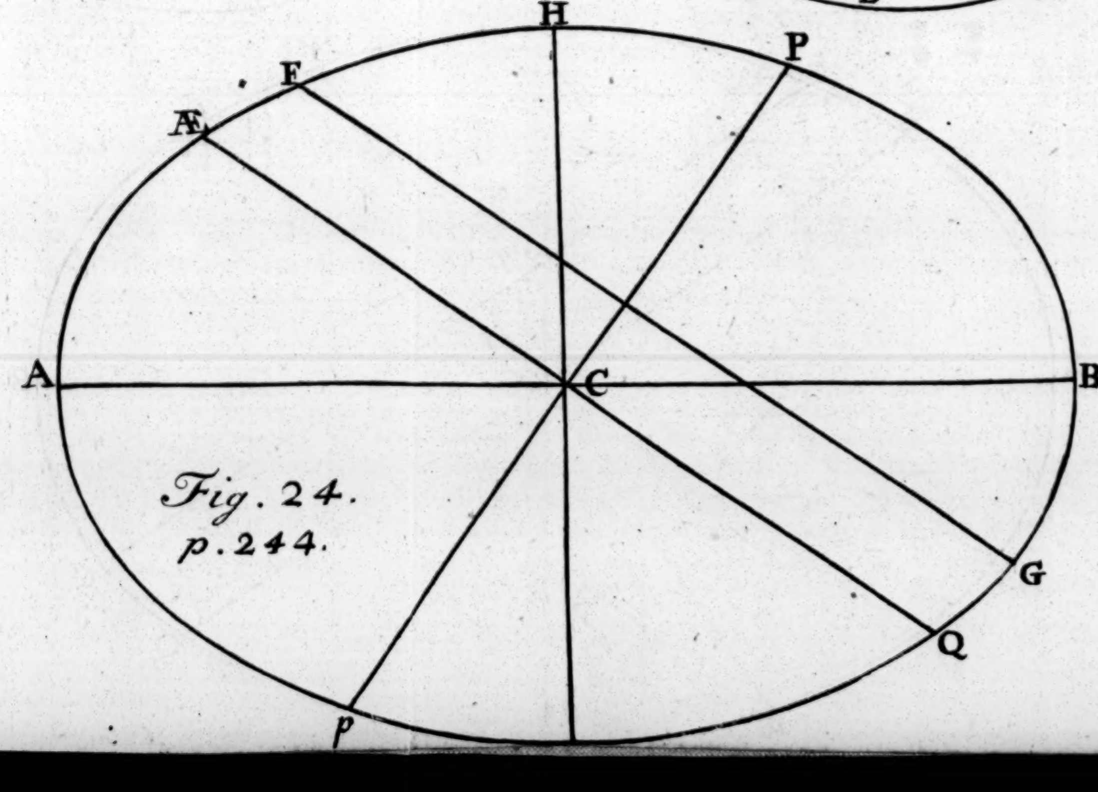

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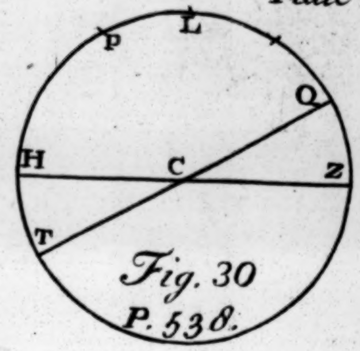

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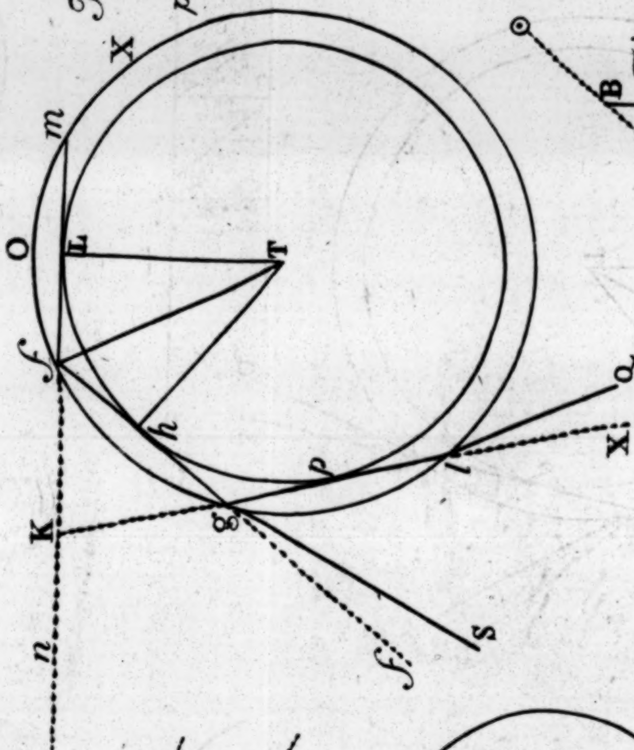

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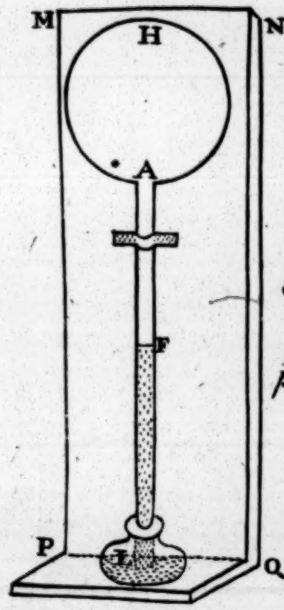

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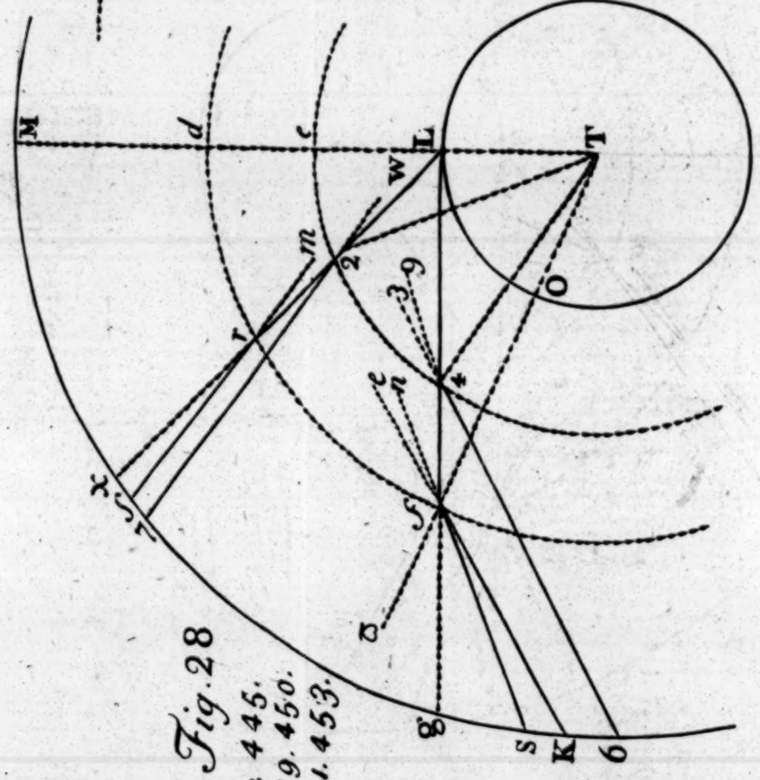

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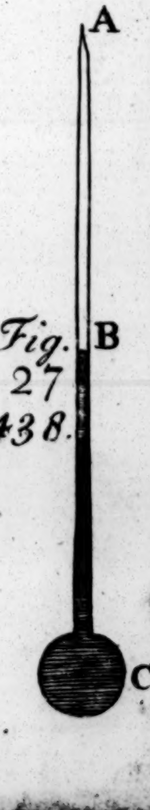

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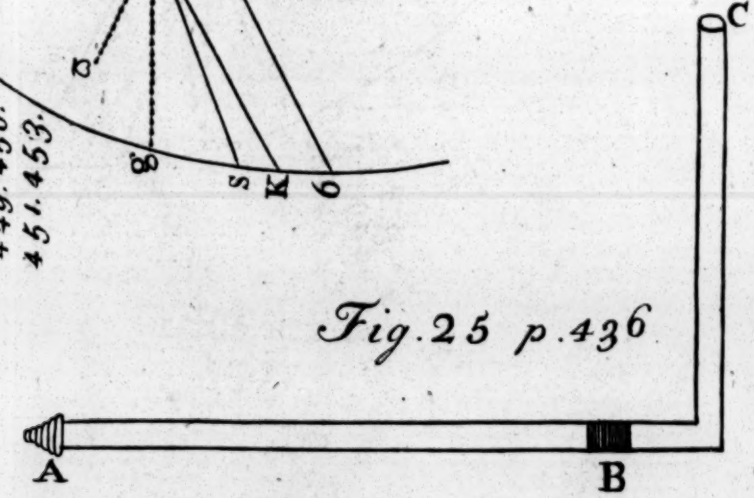

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FLORIDA
Bermuda
Bahama Isles
Cuba
Spagniola
Jamaica
Caribe Isles
THE NORTH SEA
OR
ATLANTICK
OCEAN
Variable Winds
Madera
Canary Isles
C. Blanco
C. Verd Isles
C. Verd
Gambia
Calms and Tornado's
BARBARIA
MEDITERRANEAN SEA
Egypt
AFRICA
Abassia
GUINEA
ÆTHIOPIA
THE RED SEA
ARABIA
PERSIA
INDIA
Bengall
Malabar
Cormandel
C. Comorin
Ceylon
THE ARABIAN
Zocatra
or
INDIAN SEA
The Gulf of Bengal
PART OF
THE
PERU
PACIFICK
OR
SOUTH SEA
GUIANA
AMERICA
BRASILIA
Ascension
THE ÆTHIOPICK
St. Helena
OCEAN
Merid: Londini
Congo
Angola
Mozambique
Zofala
Madagascar
Monomotapa
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Variable Winds
Variable Winds
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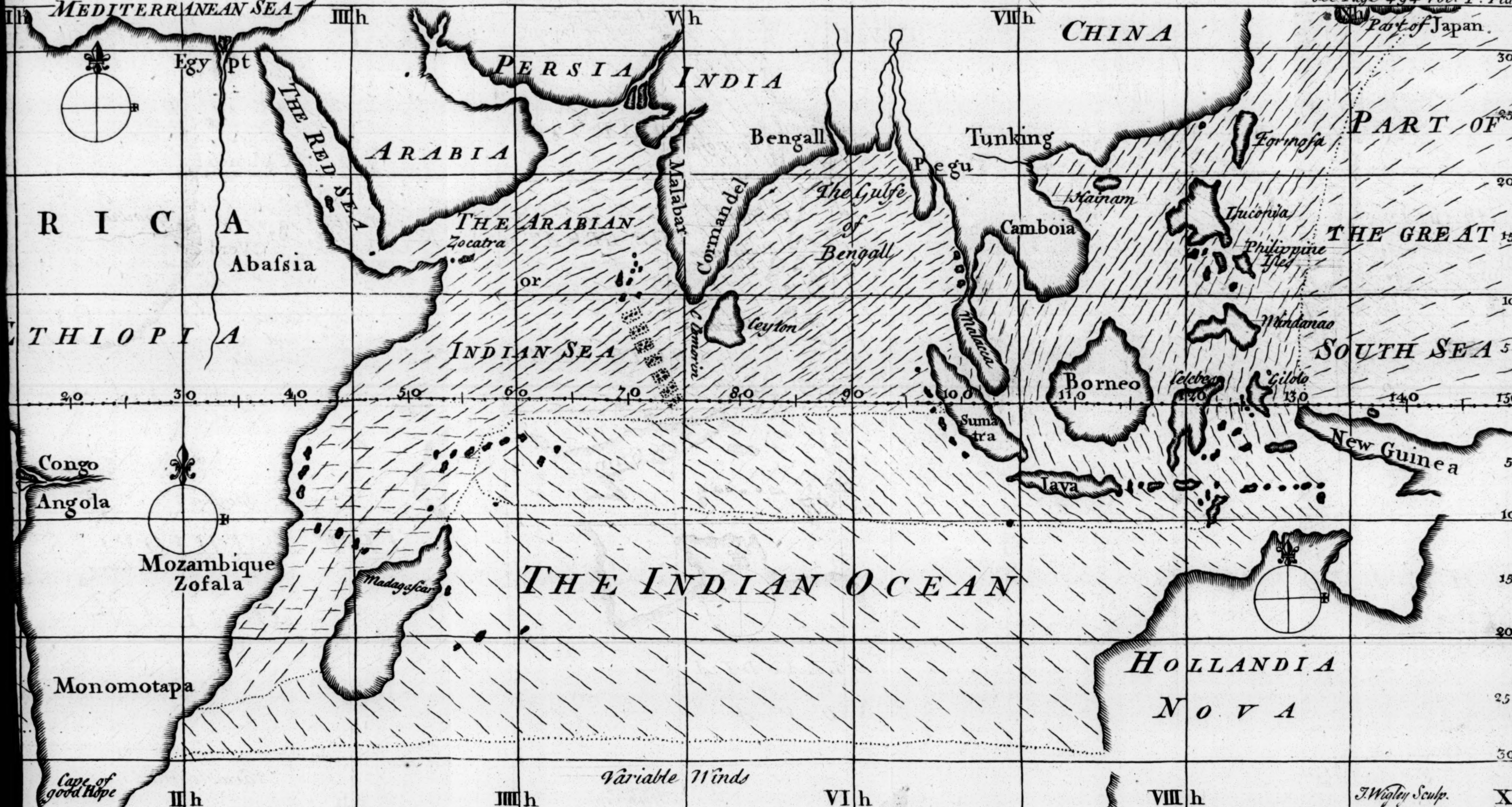

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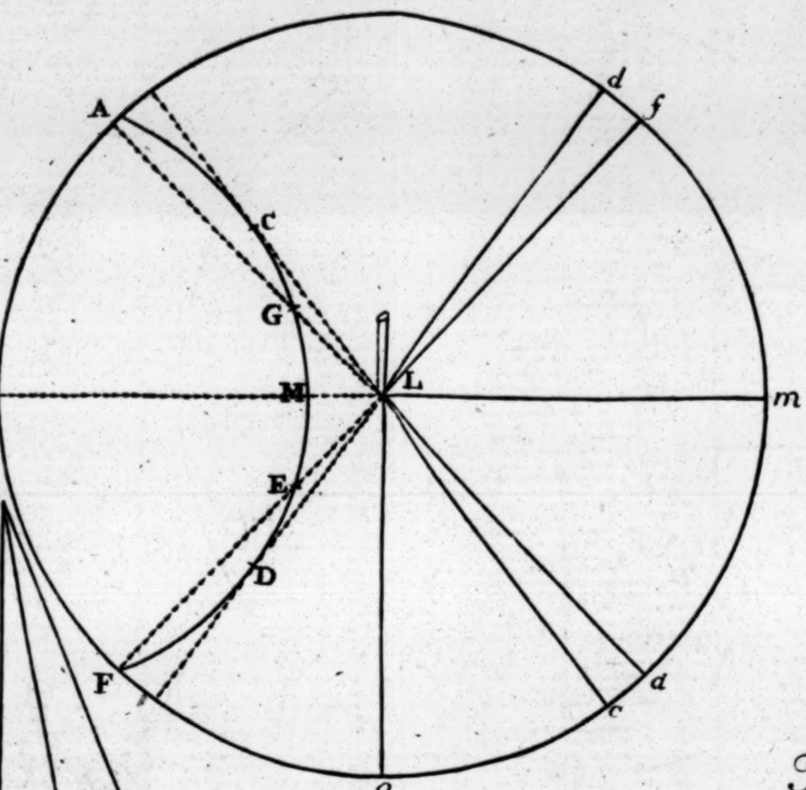

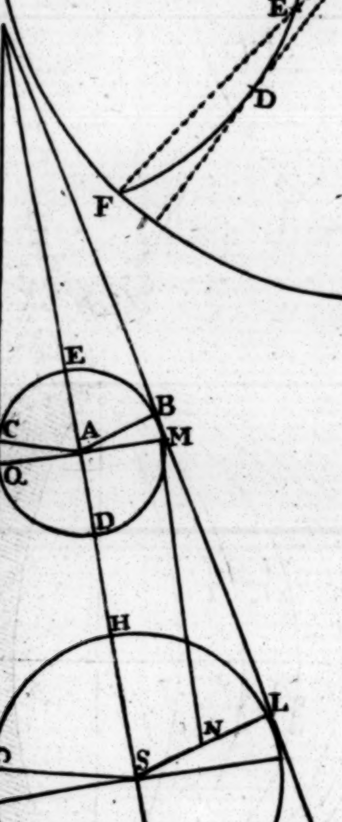

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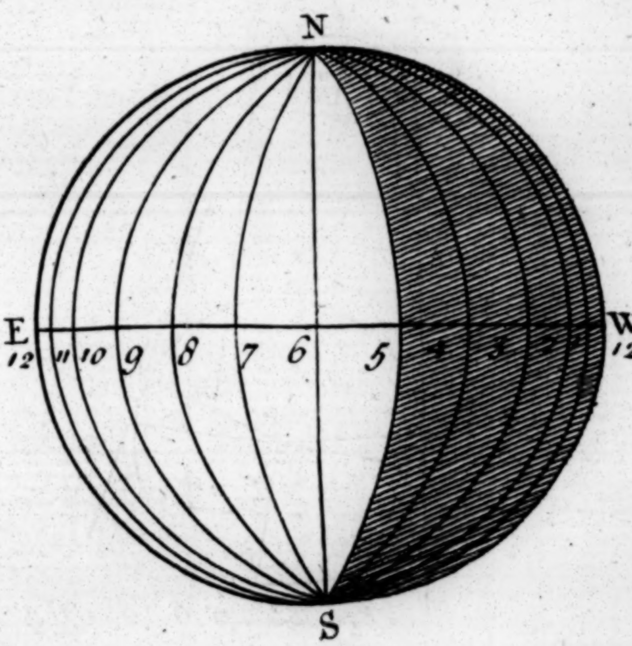

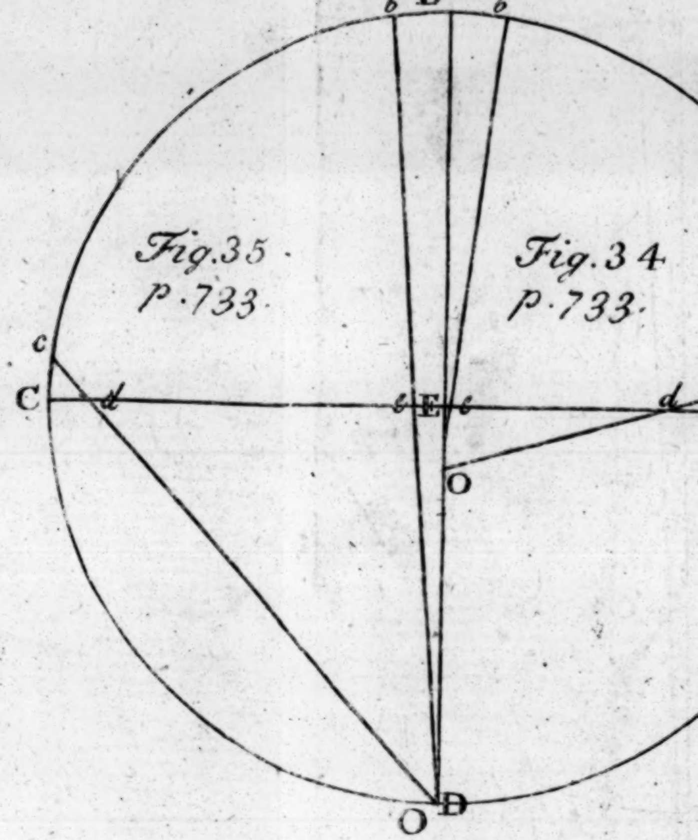

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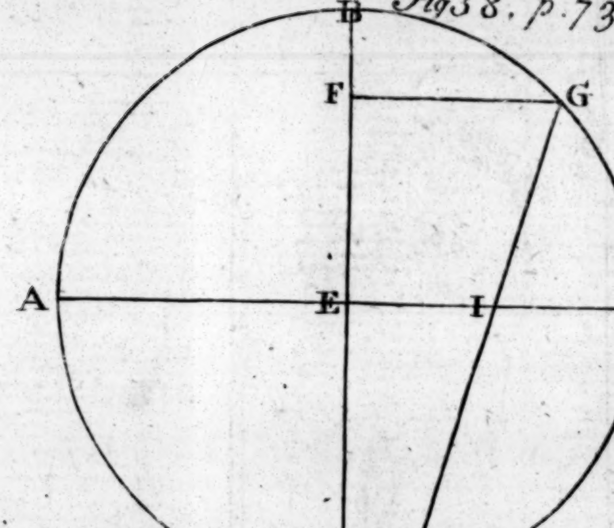
Fig.34 p.733.



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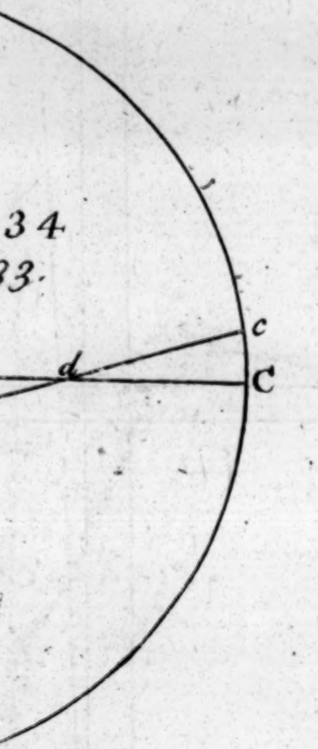

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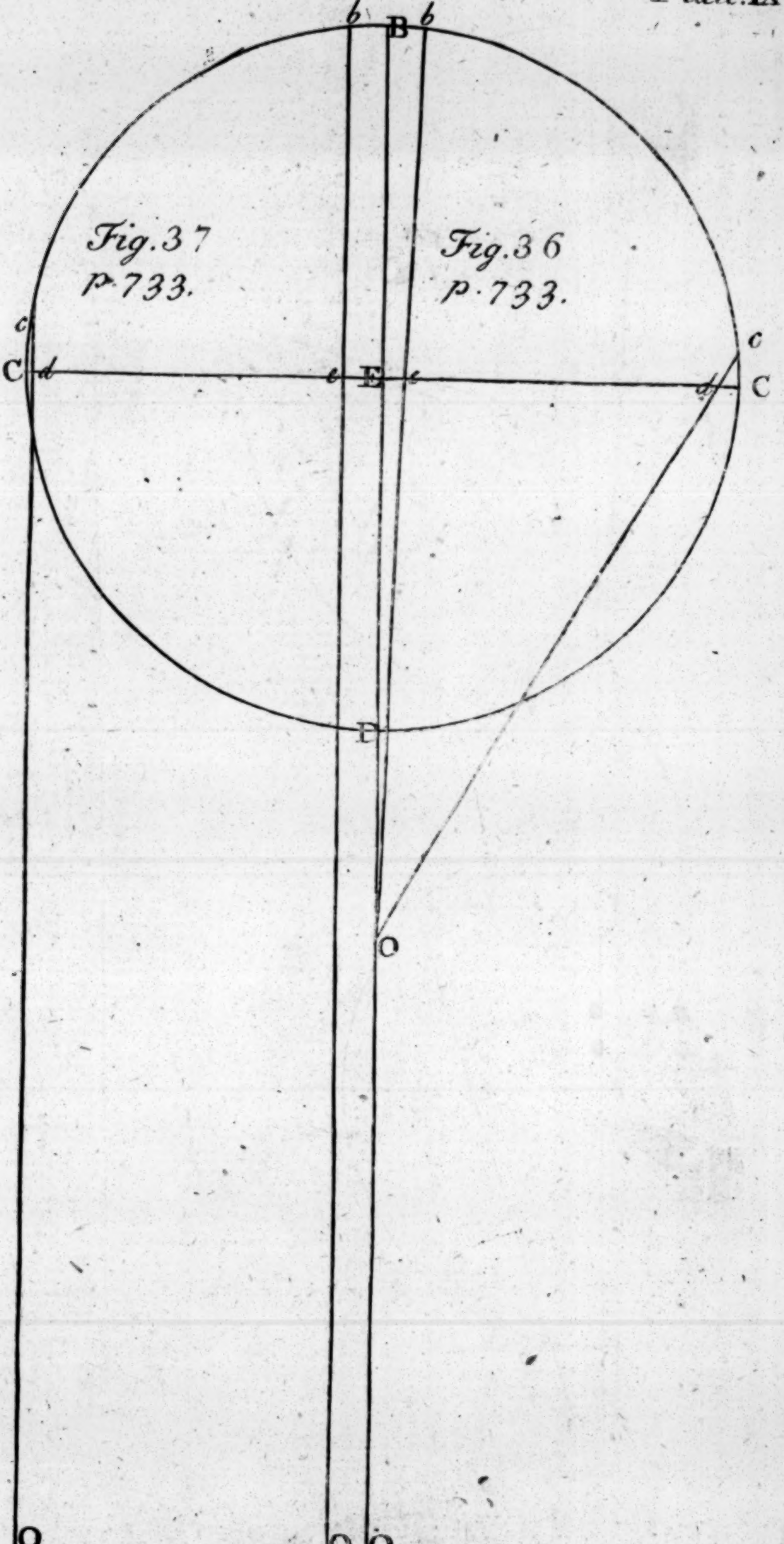

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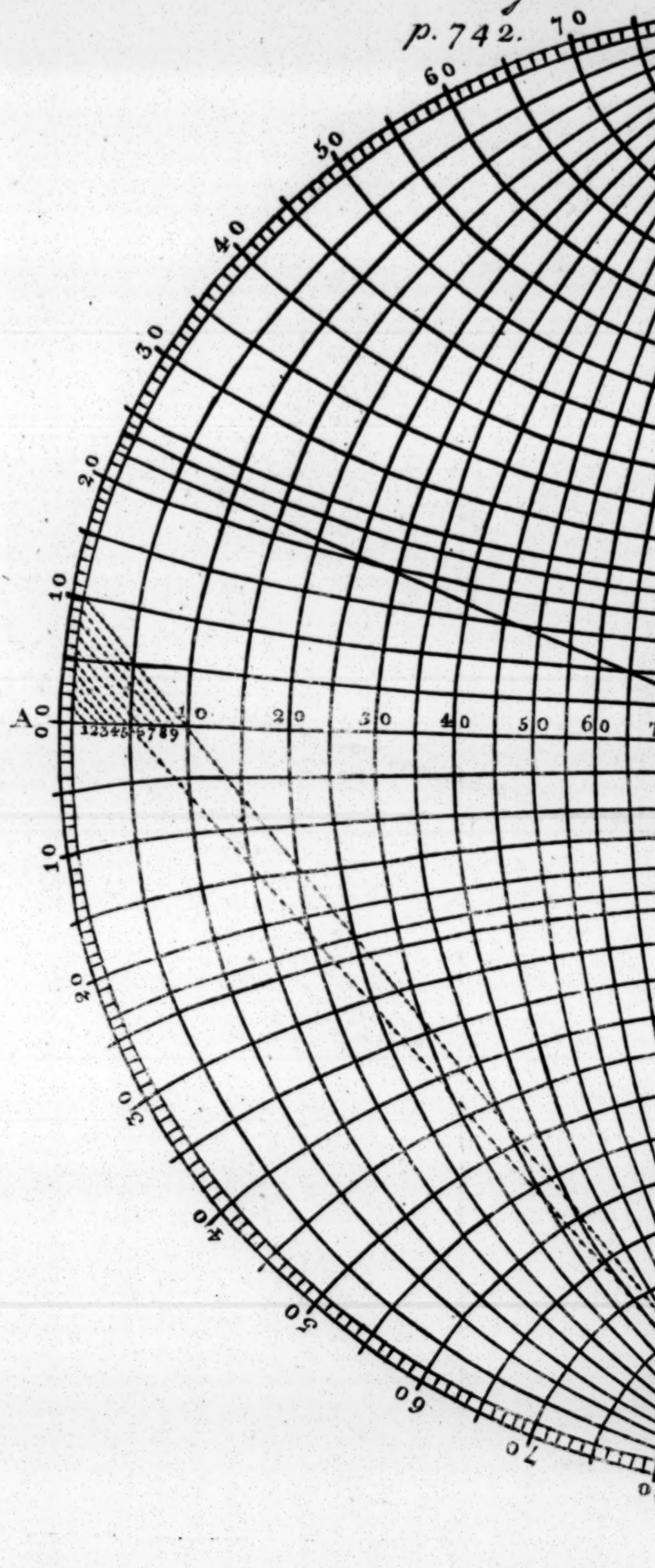

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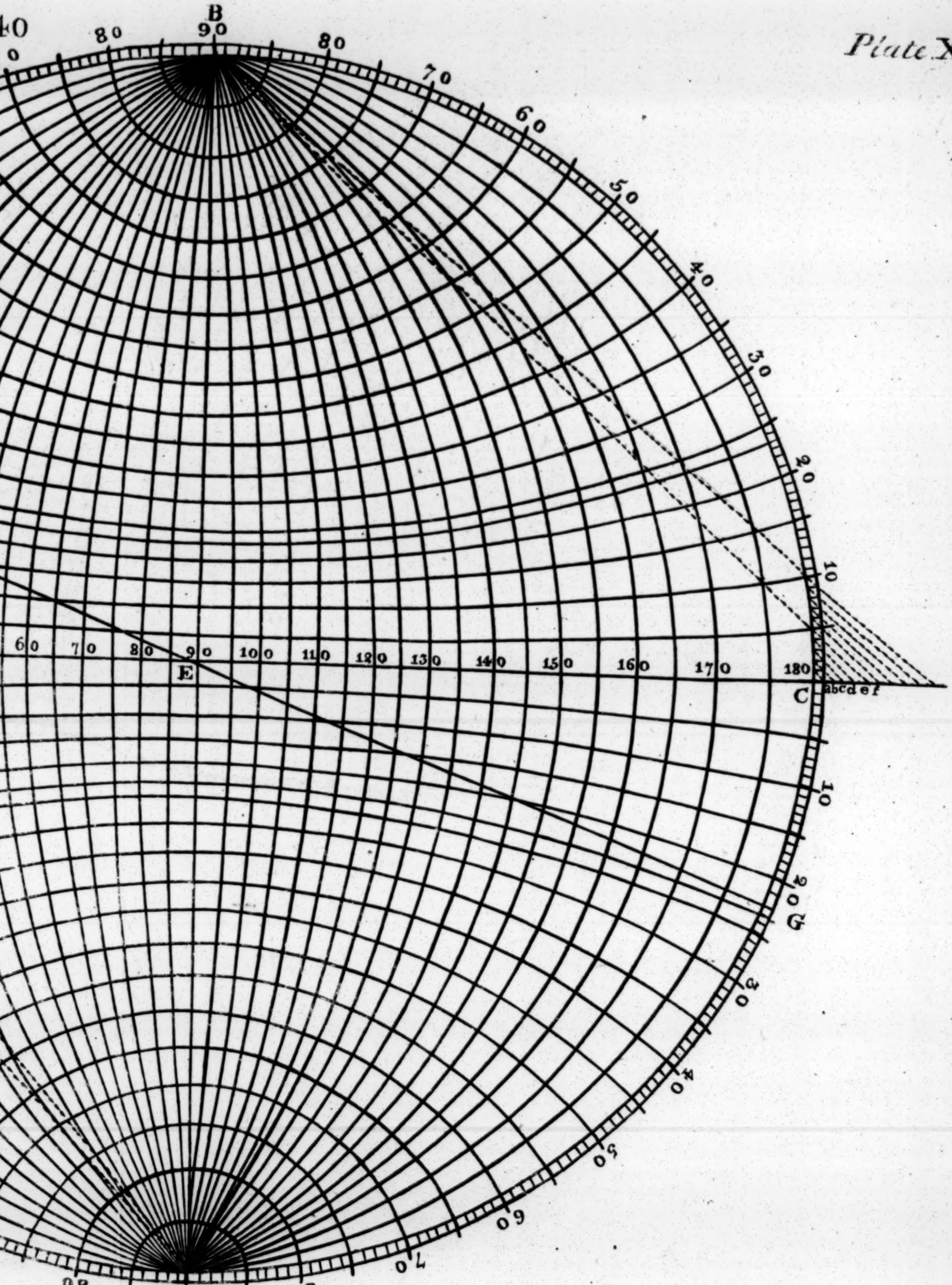

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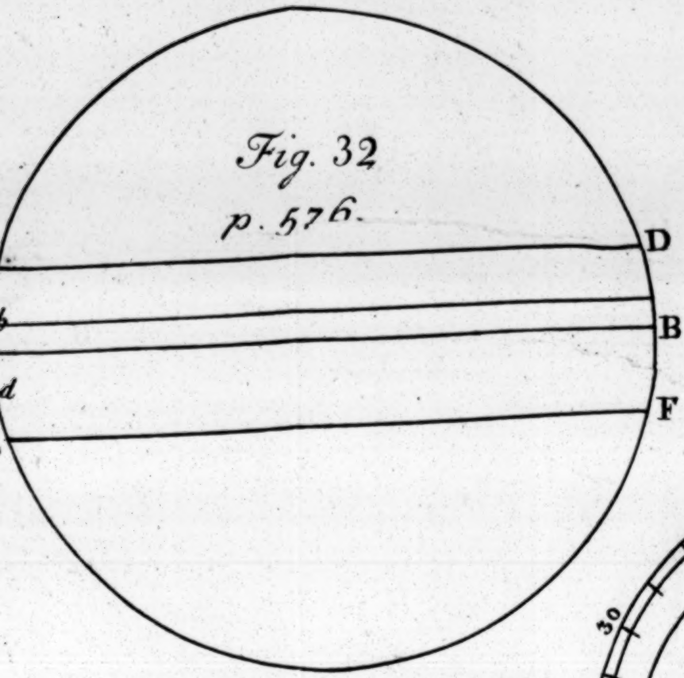

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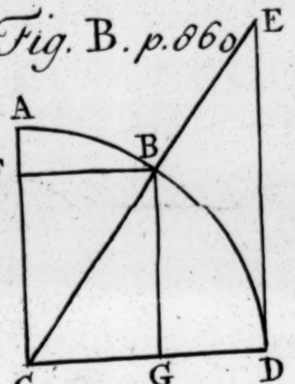

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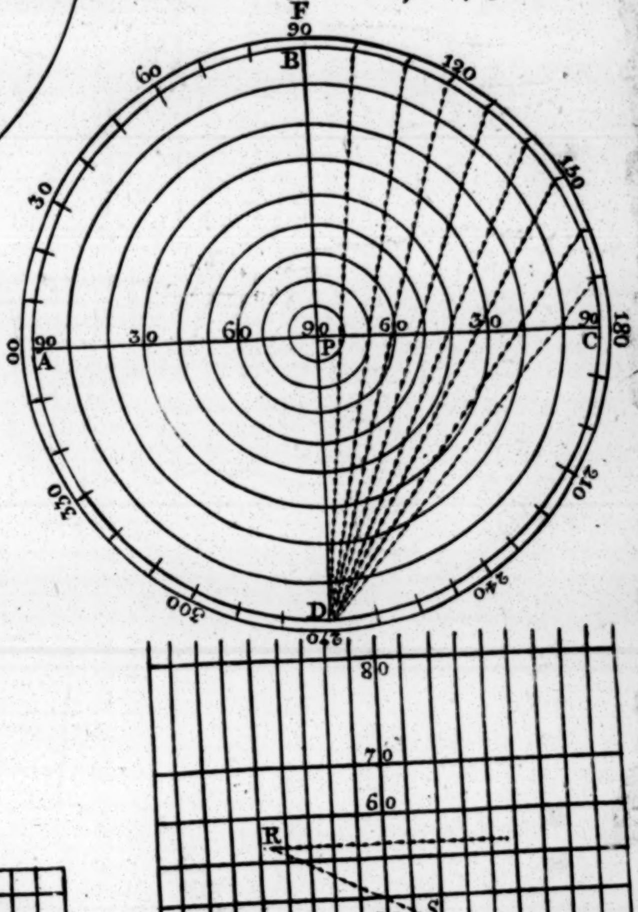

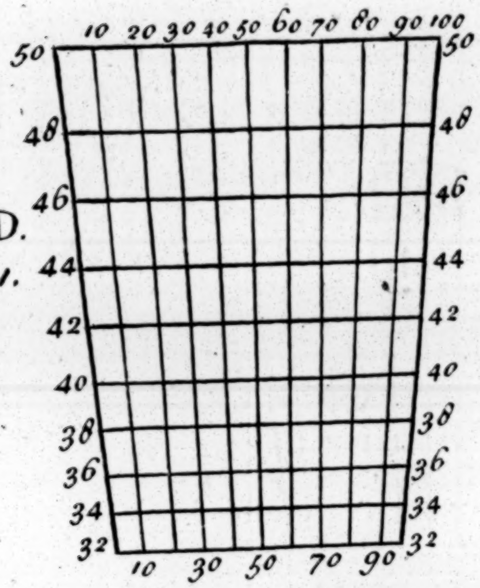

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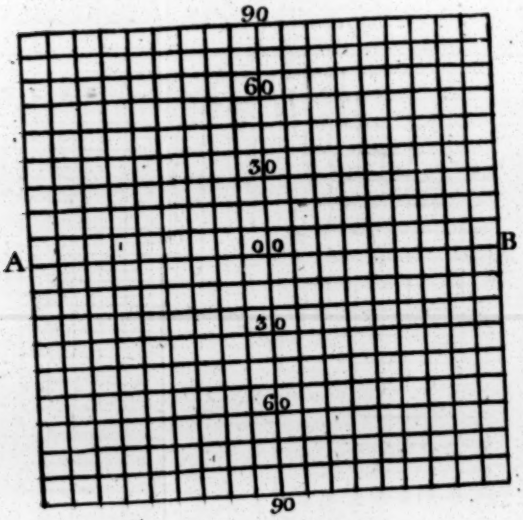

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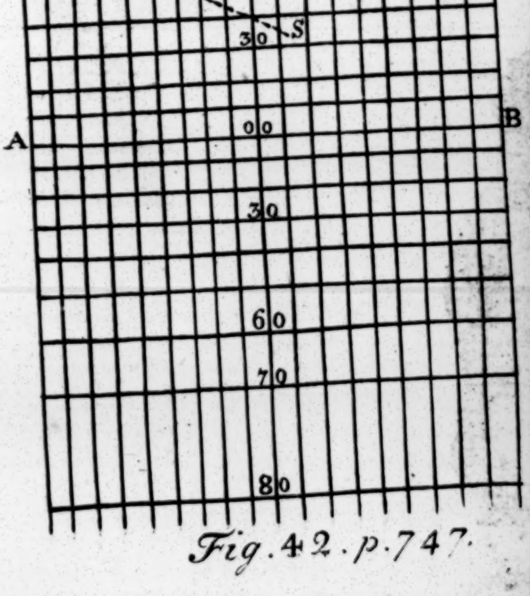

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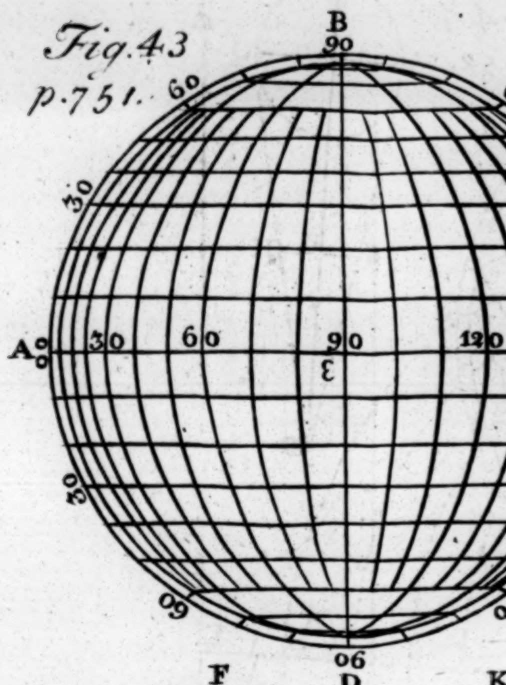

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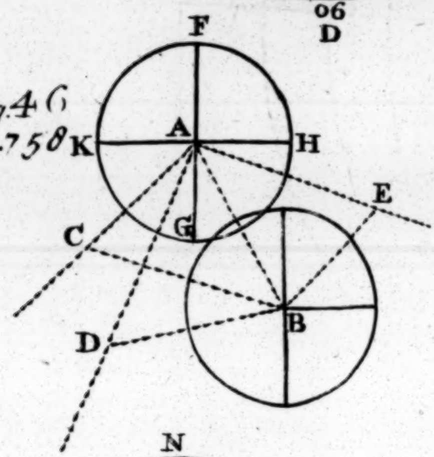

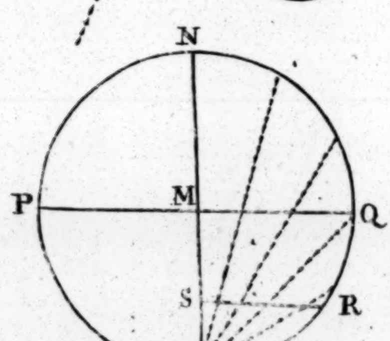

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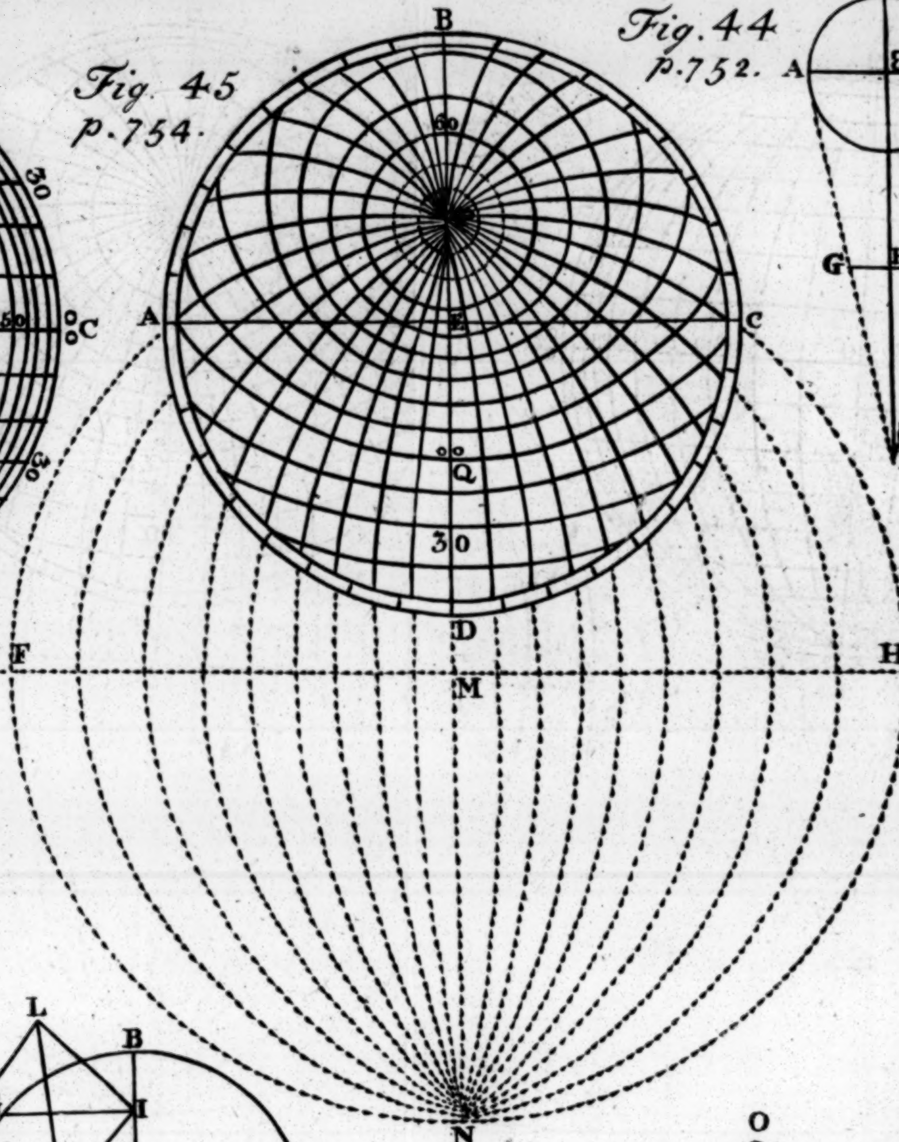

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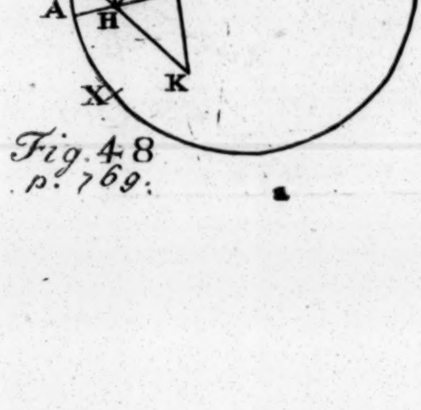

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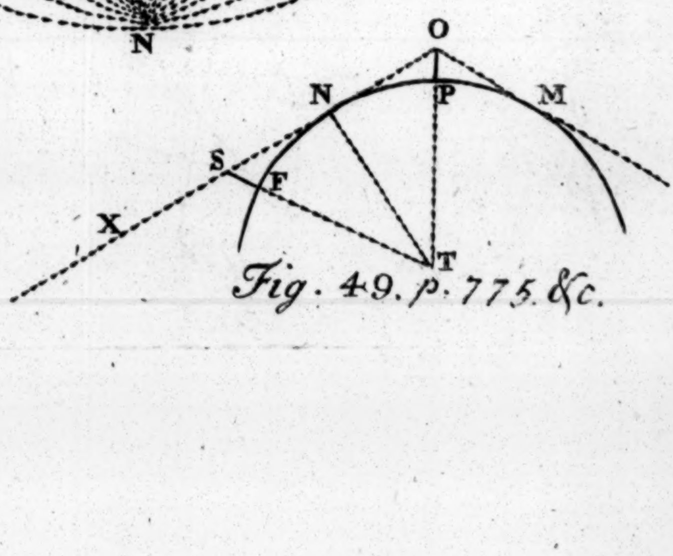

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